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LANDSCAPE ARCHITECTURE.

BY STEPHEN CHILD, MEMBER OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS AND BOSTON SOCIETY OF CIVIL ENGINEERS.

[A lecture delivered before the Boston Society of Civil Engineers, June 15, 1904.*]

WE frequently hear nowadays the questions, "What is landscape architecture and what does a landscape architect do?"

Believing, as I do, that this subject is one that may interest the engineering profession (and it is certainly one that comes in very close touch with engineering in many ways), it is my purpose this evening to try in a few words to define more clearly the meaning of the term landscape architecture; and through the courtesy of Mr. Pray, of the Department of Landscape Architecture, Harvard University, who has kindly furnished me with some of the very valuable lantern slides owned by that department, I shall be able to show on the screen a few illustrations. These, I trust, will be of interest as indicating, perhaps better than could be done in any other way, the scope of this new profession and some of the results attained by those who have practiced it both in this country and abroad.†

At the present time, even among intelligent writers, there is the greatest possible confusion and apparent misunderstanding of the terms landscape architect and landscape gardener. Recent discussion of these terms has even brought out the opinion that this

* Manuscript received July 18, 1904.—Secretary, Ass'n of Eng. Socs.

† During the course of the lecture some 50 lantern slides were shown, a few of which are reproduced through the courtesy of the *Municipal Journal and Engineer*, of New York, the lecture having been adapted from an article by the author published in that magazine for January, 1904.

calling a man a landscape architect instead of a landscape gardener is merely a "recent fad," and that the idea is absurd, "filling one's mind with images of quarries, stonecutters, creaking derricks, tapping trowels and the like, instead of with pictures of freehand dealings with sunshine and shadow, trees, flowering shrubs and leaping fountains."

I am going to ask you to look at this a little more carefully with me and see what is true in this discussion. In the first place, the term is not a "recent fad." Frederick Law Olmsted, the elder, called himself a landscape architect away back in 1856, when he first entered upon the work of developing Central Park in New York City, and the fact that he did so, and continued to so designate himself during the whole of his career, has had much to do with the general adoption of the term. But the fact that one man, even an eminent one, adopted this title is perhaps not entirely sufficient, although those of us who are familiar with Mr. Olmsted's work and with his wonderful genius and mastery of the subject in all of its details may well feel assured that he did not adopt the title without most careful thought. Unfortunately he did not in his writings, so far as I am aware, really explain his reason. He was so immersed in the great battle, then going on, for public parks for large cities, in showing their value and necessity and in laying down the principles and executing the work of these great undertakings, that he apparently had little time to explain fully why he assumed the title. We may, however, be perfectly assured that he had reasons, and most excellent ones, and a little study of these may be interesting and profitable.

In the process of the development of mankind there has been noticeable a constantly increasing tendency toward differentiation and specialization, each step in the process being a slow one, and, as a rule, taken at first by some man or group of men trained in some other line. In this way have come about many new forms or fields of work, each adapted more or less from others of a previous and perhaps lesser civilization. Each new profession, or branch from an older one, demanded and received a new cognomen. This process of differentiation has developed more or less clearly defined groups of men, as, for example, the professions of the ministry, medicine, law, civil engineering, architecture and so on.

Fifty years ago, when Mr. Olmsted began this landscape work, there was beginning to be a demand in this country for men to do a certain line of work that was intrinsically quite different from that previously carried on by either the architect, the engineer or the gardener, and yet work that embodied some of the principles here-

tofore utilized by all of these men. Here was this great tract of land, now known as Central Park, to be developed and made beautiful, for the purpose of providing the crowded millions of the great city of the future with the opportunity "for a form of recreation to be obtained only through the influence of pleasing natural scenery upon the sensibilities of those quietly contemplating it." This was a new problem for this country, and indeed for any country, for none of the great parks in Europe now utilized for this purpose were originally created for anything of this sort. They are chiefly the result of developing land that had originally been set aside as hunting forests by the great nobles or rulers of Europe.

I think it will be generally conceded that New York was most fortunate in its selection of the master mind to work out this problem, and that the work of creating Central Park has been most successfully designed and executed. Mr. Olmsted saw clearly the greatness of the task and the differentiation of this form of design from that of the architect or engineer and certainly from the work of the gardener. He chose to call himself a landscape architect. Let us, therefore, look into the meaning of these words and see whether they are not well selected and worthy of our respect and of more general adoption.

That most delightful and interesting writer, Philip Gilbert Hamerton, says of landscape: "We use the word in two distinct senses—a general and a particular. In the general sense the word 'landscape,' without the article, means the visible material world—all that can be seen on the surface of the earth by a man who is himself upon the surface; and in the special sense 'a landscape' means a piece of the earth's surface that can be seen at once, and it is always understood that this piece will have a certain artistic unity or suggestion of unity in itself"; and further he adds, "although the word refers to the natural land, it does not exclude any human works that are upon the land." The word is derived from two good Anglo-Saxon parts, "land" and the suffix "scape," corresponding to "skip" or "ship," as in the word "friendship," meaning "the state or condition of being." Landscape then means "the state or condition of being land." When we come to add the word architecture, however, the connotation conveys to many people a wrong impression, but it should not, for in its early and primitive meaning the word architect meant simply and solely "chief workman" or "master artisan." It is well, I believe, for us to recall this earlier meaning of the word at the present time.

It is quite largely the architect himself who is responsible for any wrong impression that may have developed in the use of the

term landscape architect; as many have assumed that, because the word architect is used at all, the term landscape architect means simply an architect who meddles a bit with the landscape immediately surrounding his buildings. Many architects have done this, with regrettable results both to the client and to the profession of landscape architecture. I think it is but fair to suggest that, if the architect solves the problems of his buildings successfully, he may well leave to the landscape architect the matter of designing the surroundings for them, realizing that his own architectural problems are many and difficult, and that the trained landscape architect can, by co-operating with him, greatly improve the net result; for, as we all know, the effect of many a successful building has been seriously impaired by lack of a proper setting.

What Mr. Olmsted meant when he termed himself a landscape architect was that he was aiming to be a master artisan in matters pertaining to land, having regard both to the beauty of its appearance and to its use. In a very real sense such work covers agriculture, forestry, gardening, engineering and the elements of architecture.

Landscape architecture has been defined as "a group of activities which include horticulture, architecture, civil engineering and agriculture." Humphrey Repton, a great English authority on matters of this sort, says that in order to carry out this line of work one must possess not only artistic ability and taste, but "a complete knowledge of surveying, mechanics, hydraulics, botany and the general principles of architecture." We may well weigh his words, for Humphrey Repton was a cultivated English gentleman of great refinement and good taste. He was the first Englishman from such a grade of society to undertake the planning or designing of country estates. Kent, one of his predecessors in this line of work, was a coach painter by trade, who possessed some artistic taste, but little culture. "Capability" Brown, Repton's most famous immediate predecessor, was a gardener, who, by association with men of refinement and by his tact and native ability, worked his way up to an honorable place; but Repton was a well-educated English gentleman, who had traveled and studied much. Repton, however, called himself a landscape gardener, as did all of the others at that time, but Mr. Olmsted chose to avoid that term for several reasons. In the first place, these workers in landscape design in England had confined their efforts almost entirely to the design of country estates. The term landscape gardening was, I believe, first used by the poet Shenstone to mean more particularly an informal or picturesque treatment of the grounds of an estate, as distinguished from the

older style of formal treatment that had been in vogue and which had been carried to such excess. In the early part of the eighteenth century formality had been carried to the point of puerility. A reaction set in, due to numerous causes, and the "new style," or so-called "English style," was introduced by Kent and others, who, as Sir Horace Walpole enthusiastically exclaimed, "leaped the wall and saw all nature was a garden," and so in fact it is in those delightful parts of old England in which they labored; those country estates with their deer parks and pleasure grounds. These men made a practice of designing country places in an informal or naturalistic manner, and termed this landscape gardening. They were in favor of abolishing all formality, and they themselves carried their theory to excess.

Later, in the latter part of the eighteenth century and the first of the nineteenth century, men like Repton came forward, realizing that formality had its place and value, and began to use it under certain circumstances, but still called themselves landscape gardeners. This latter use of the term was a serious twisting of the original meaning; for a garden is, properly speaking, a place engirt, inclosed or set apart and highly cultivated. Landscape is, as we have seen, a piece of the earth's surface that can be seen at one time by a man who is himself standing upon the earth, and may, of course, mean a broad stretch of country not at all inclosed.

There is another important point and one that has not been particularly mentioned in discussions of the term landscape architect, one that I have already alluded to, namely, that these English landscape designers were engaged almost exclusively in the preparation of plans for country estates. These were, of course, not always large, and often were walled in or engirt, and, therefore, perhaps in a sense gardens. Mr. Olmsted, in 1856, had before him not such a problem, but that of designing a great public park for a large city. This work was not gardening in any sense of the word; it was something quite different. It was a work of design, a work that could be undertaken and successfully carried out only by a "master artisan in matters pertaining to land." Here were to be developed, and we know how well it has been done, broad peaceful landscape effects, giving the tired city dweller opportunity for restful contemplation and relief from city sights and sounds. These were to be designed and executed where none had existed before, and in such a way that there should be no obtrusive evidence of man's elaborate control and no marring of the pleasing, restful effect by such garden elements as beds of geraniums or rare and striking shrubs clipped into formal shapes; in other words, no gardening. This was

what he termed landscape architecture. The French landscape designers had already adopted this term, their phrase, architecte paysagiste, meaning simply landscape architect.

Many of Mr. Olmsted's great works are familiar to us all. They include Central Park, New York; Prospect Park, Brooklyn; the almost unrivaled Park System of Boston; the great work designed by him at the World's Fair at Chicago; and almost innumerable country estates, notably Biltmore, at Asheville, N. C., the mere enumeration of which serves to show some of the diversity of the work, and even the most casual observer can see in them some of the reasons why this sort of work is not properly to be called landscape gardening. A gardener, as commonly understood, is one who cultivates a garden. He may, and of course should, know a great deal about botany and horticulture, but when you come to associate the word garden with landscape there is implied simply that we have a gardener who cares for a garden having a naturalistic or landscape character; the absolutely essential factor of creative design disappears. Expensive mistakes have often resulted from employing on landscape work a person who was simply a common gardener and ignorant of the principles of this sort of design. Art commissioners would not think of employing a man to design a monumental public library or city hall simply because he was a good stonemason.

Landscape architecture is then, as Charles Eliot, one of Mr. Olmsted's gifted disciples, has well said, "the art of arranging land for use and the accompanying landscape for enjoyment." Landscape gardening is, it seems to me, a term conveying in itself confused ideas, but used, if at all properly, simply to cover that part of the landscape architect's work which has to do with the development of formal or natural beauty by the simple process of removing or setting out and caring for plants. This is quite secondary to the matter of designing a general scheme for the development of land for any given purpose.

The problems with which a landscape architect has to deal are many and varied. Among them are, as we have seen, the design for a great country park for a large city, where the object is, or should be, to afford perfect relief and rest to the tired citizen by offering to him and preserving for him the contrast of broad, restful rural scenery unmarred by any of the sights and sounds of city life. This is a great problem, involving many considerations as to choice of the tract of land, its bounds, its present scenic effects, its accessibility, the design of roads and paths through it, so that the public may enjoy, but not destroy, its beauties. Fig. 1 shows some of the

Fig. 1. View in part of Boston's Park System.

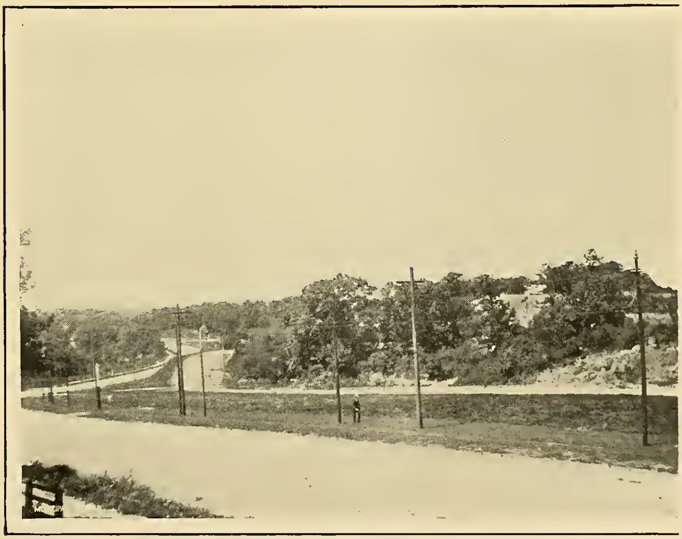


Fig. 2. View of portion of Commonwealth Avenue, a part of Boston's Boulevard System.

Figs. 3 and 4. Views on the Riverway, a part of Boston's Parkway System leading to Franklin Park.

Fig. 5. Charlesbank Playground, Boston.

Fig. 6. A Country Estate near Boston.

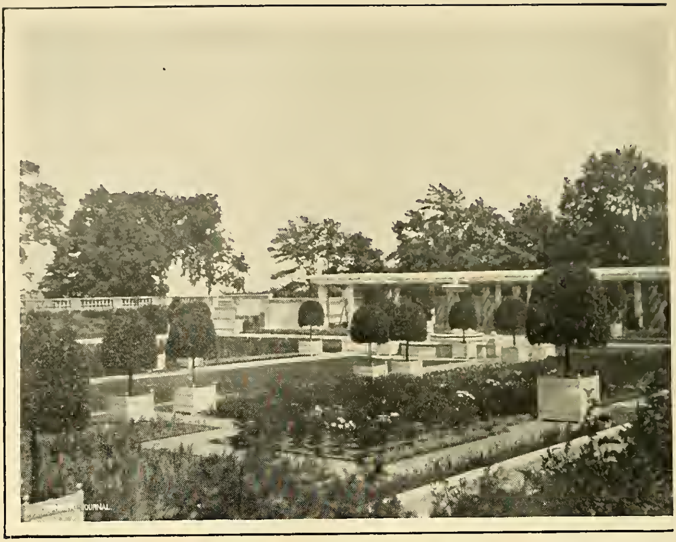


Fig. 7. An American-Italian Garden.

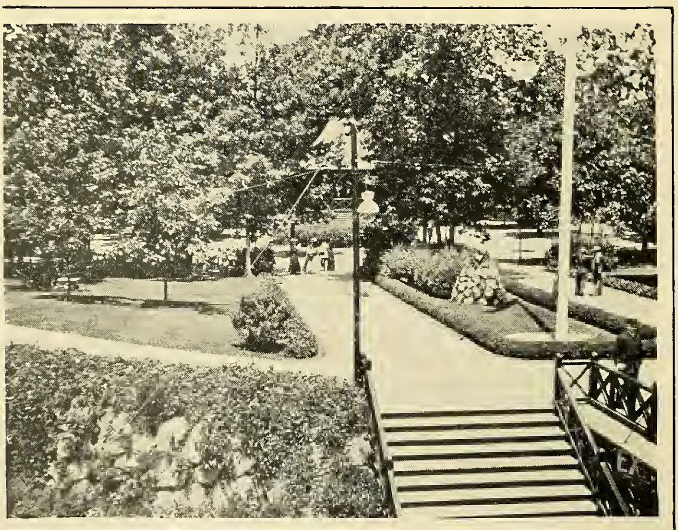


Fig. 8. Part of a Street Railway Company's Amusement Park.

pleasing, restful results of landscape design, being a view in part of Boston's Park System, and, of course, only one of many which might be given to illustrate this part of the landscape architect's work.

Then there are approaches to the park, "parkways" so called, to be designed, involving much careful thought as to location and details of grades (Fig. 2). Perhaps a hitherto neglected sluggish stream, whose banks had been an unsightly dumping ground, can be transformed, by careful design, into a beautiful parkway.

Figs. 3 and 4 are scenes of what is known as the "Riverway," a part of Boston's Parkway System, leading from the city proper to Franklin Park, and are especially good examples of landscape design; for, beautiful and natural as they now appear, there is hardly a line or bit of vegetation, except the older trees, that has not been placed by the hand of man where we now see it. Fifteen years ago this part of the town was one of the ugliest sites imaginable. A brackish stream struggled along through tangled masses of sedges and swamp land. Now all is beauty of the most restful sort, but every particle of it is the result of design. This is not landscape gardening, but landscape architecture, the work of a "master artisan in matters pertaining to land."

Other problems for the landscape architect are the planning of the more or less formal paths and planting of the City Square; the development, in a pleasing way, of the children's playground (Fig. 5); or the surroundings of the schoolhouse, with its school garden, now so necessary an adjunct to American educational methods. Then, too, the stately Public Library or City Hall must have its appropriate landscape setting.

The landscape architect should share with the architect the design of country estates and homes (Fig. 6), the two working together to place the house and the buildings properly as regards terraces, approach roads and paths, the landscape architect using his trained taste and experience in working out appropriate changes in the surrounding scenery, perhaps screening, by judiciously placed planting, an unsightly neighboring building. There may be a formal garden to design, with its paths, ramps, terraces and pergolas (Fig. 7).

Then there is the important subject of the design for naturalistic treatment of reservoir basins. This is a most important class of work, and one in which the engineer can effectually co-operate with the landscape architect. I can but allude to this matter very briefly, but the results of this branch of landscape design certainly add greatly to the beauty of such basins, and, by the pleasing naturalis-

tic treatment of shore line and embankment, make them beautiful lakes rather than stiff and ugly artificial reservoirs. An entire lecture might well be devoted to this branch of the subject, and the superiority of such naturalistic treatment over the former mathematical regularity or partial formality of the more common mode of treatment of such basins can be clearly shown, and I trust those of you who have such problems to solve will remember the importance of looking at them in this way and of co-operating with the landscape architect in obtaining such desirable results.

There is also the question of designing, for the street railway companies, amusement parks for their thousands of patrons (Fig. 8). In this case provision must be made for the necessary band stand, open-air theater and other amusement features, and great care must be exercised in securing ample approaches and the like.

There is much for the landscape architect to do in the laying out of new suburbs for our growing cities, residential parks, neighborhoods of summer cottages at the mountains or the seashore, and there are the grounds of hospitals, educational and other institutions, of hotels and railroad stations, to be designed.

In the time at my disposal it is impossible to more than briefly touch upon the many and varied fields of work open to the landscape architect or to explain more fully the principles involved in such design. I can only add that all of these problems involve the thoughtful care of trained minds, and in all of them the first and fundamental purpose should be to ascertain, by careful study of the existing natural conditions, what the "genius of the place" really is, what it is that nature herself hints at, and then, by taste and judgment, to so design the improvements that they will harmonize with the natural tendencies of the place, and be both practical and useful, always remembering what Charles Eliot has so wisely said, that "what would be fair must first be fit."

"SUGGESTIONS FOR STEEL-CONCRETE CONSTRUCTION."

By John C. Anderson, Member of the Louisiana Engineering Society.

[Read before the Society, April 9, 1904.*]

In taking this topic for discussion to-night, I am aware of my own limitations in dealing with such a subject. In the first place, such construction is really only in its infancy in America, and very few of us have had access to reliable translations of the writings of those French engineers who have put the results of their studies on paper. In the second place, the more one has to do with concrete construction—and particularly with construction wherein there is an attempt made to scientifically combine steel and concrete to the end that these materials shall act together and in a way to produce the best results—the more one learns to avoid dogmatism.

I shall, therefore, attempt to set before you only a few of the generalities which I conceive to be fundamental, together with an application of steel-concrete construction which I deem particularly adapted to use in this vicinity. It is my intention to treat the matter from a practical rather than from a technical standpoint.

In the very beginning of this discussion it is well to study the working qualities of both steel and concrete separately, before we consider them in their combined relation.

We note, then, that it is easy to ascertain the strength of a given quality of steel; and, but for one factor, it would be equally easy to find the strength of concrete, and that factor is the mixing. The manufacture of steel has reached the stage where, with given chemical properties, the physical properties are almost absolutely known. The same is true of concrete, but, when the cement is combined with the aggregate, the "personal equation" enters so largely into the mixing that we are at once confronted with the fact that, in most cases of actual construction, the strength of the concrete is largely indeterminate.

This brings me up to what I consider the most important rule in concrete construction—a rule which I evolved for my own use, and which I present for your consideration. It is: "Never use concrete in such a manner that, if portions are found defective, they cannot be removed and replaced without endangering the stability of the structure, unless the concrete can be mixed and placed in position under the eye of an experienced engineer."

* Manuscript received May 18, 1904.—Secretary, Ass'n of Eng. Socs.

It is well said that "every rule has its exceptions." The exception I habitually make to the above rule is in the consideration of larger masses (such as bridge piers), where the inferior strength of portions of the work will not affect its usefulness, even though such defective portions are not removable.

Having noticed the relative certainty with which we may calculate on the two materials in our designing, let us proceed to the consideration of their use in conjunction.

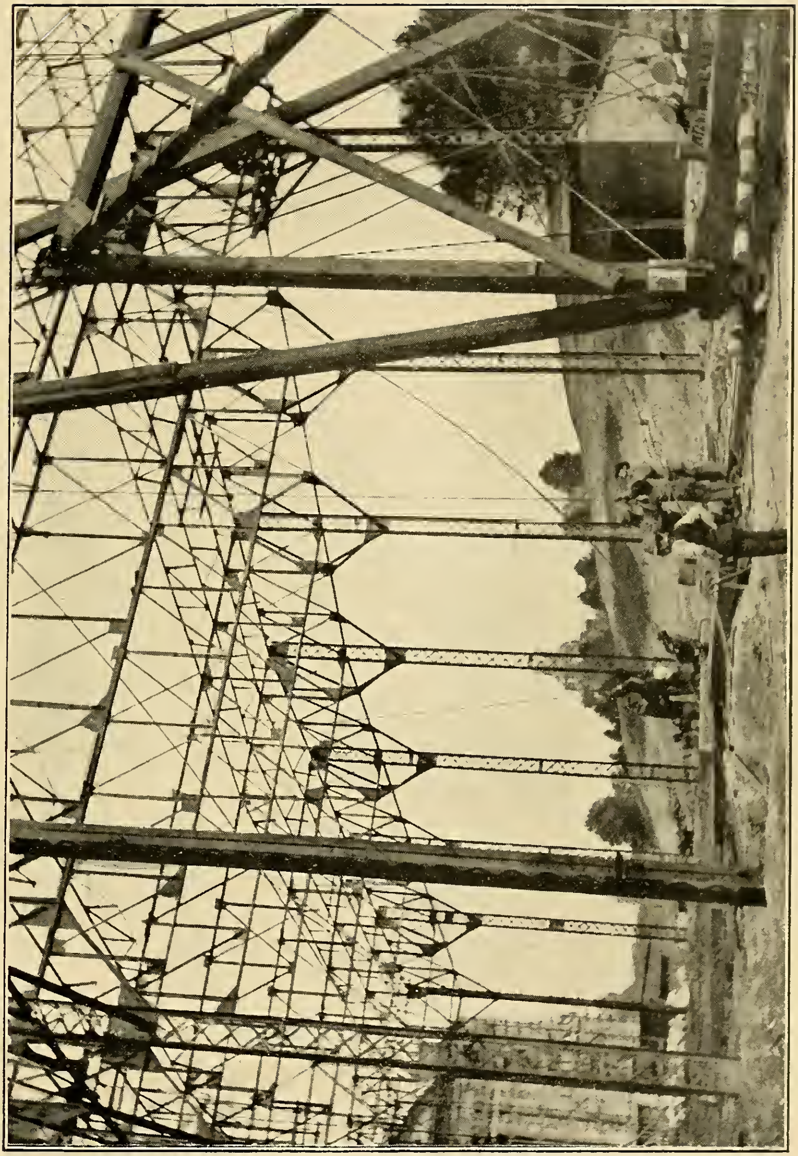
The first point of interest, to an observer of their united action, is the firmness with which cement mortar adheres to steel. So close, indeed, is this adhesion, that I am almost inclined to regard it as a fusion rather than an adhesion. The affinity is such that there is a stronger bond between the mortar and the steel than there is between the mortar and the materials usually composing the aggregate. This has been demonstrated to me on a number of occasions, both by experiment and in actual construction. No doubt many of you have had occasion to cut the concrete away from a steel beam, and have noticed that the chisel would cut into the beam but would not cause the concrete to "flake off," which would have been the case but for the close adhesion of which I speak.

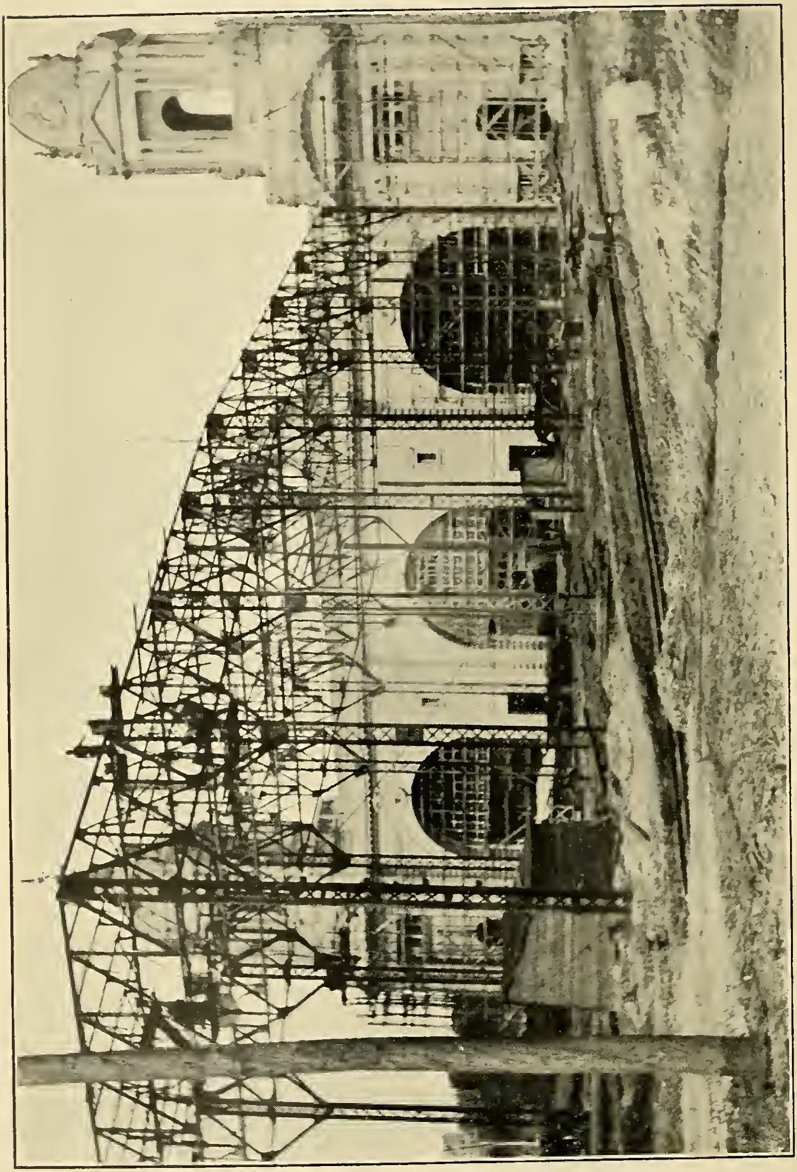
A second point, which we will do well to note, is the fact that steel and concrete have practically the same coefficient for expansion by heat. This fact enables us to proceed with confidence in the design of structures which will be subjected to variations of temperature.

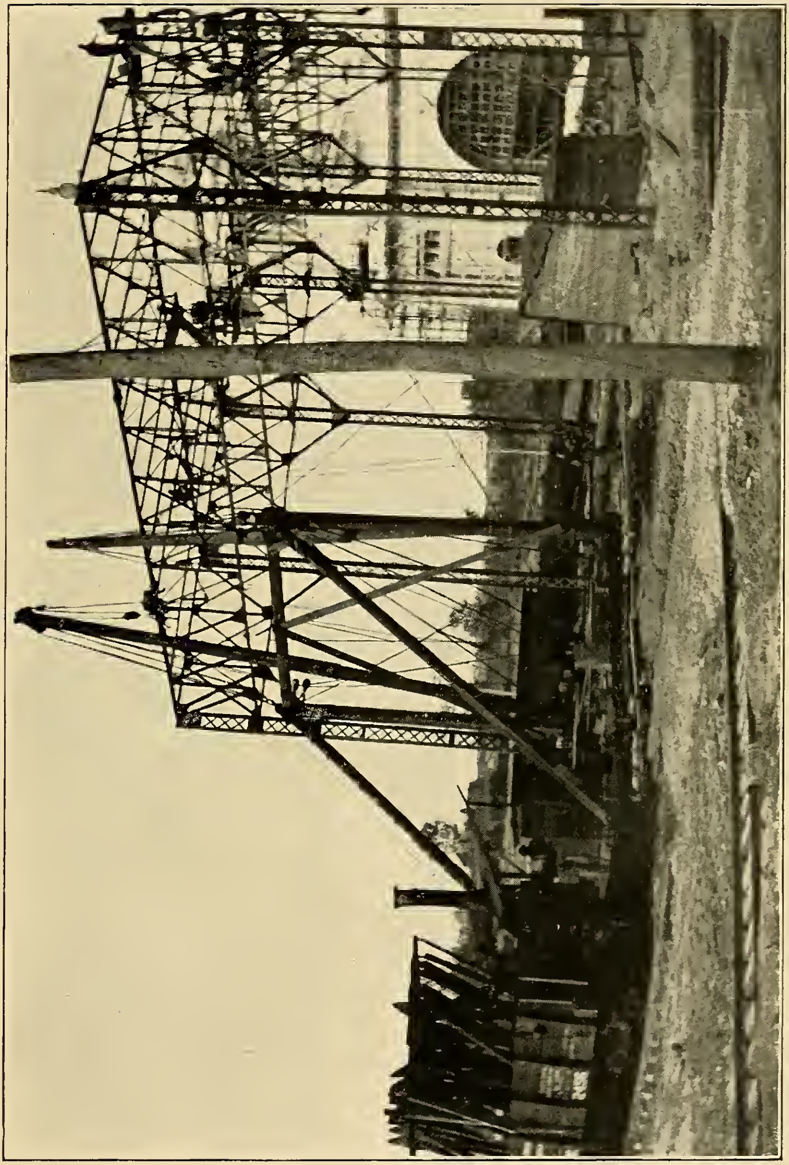
The only other general point to which I would call your attention is the well-known fact that steel develops its greatest strength when in tension, while the greatest strength of concrete is developed under compression; and this is equally true when they are used together.

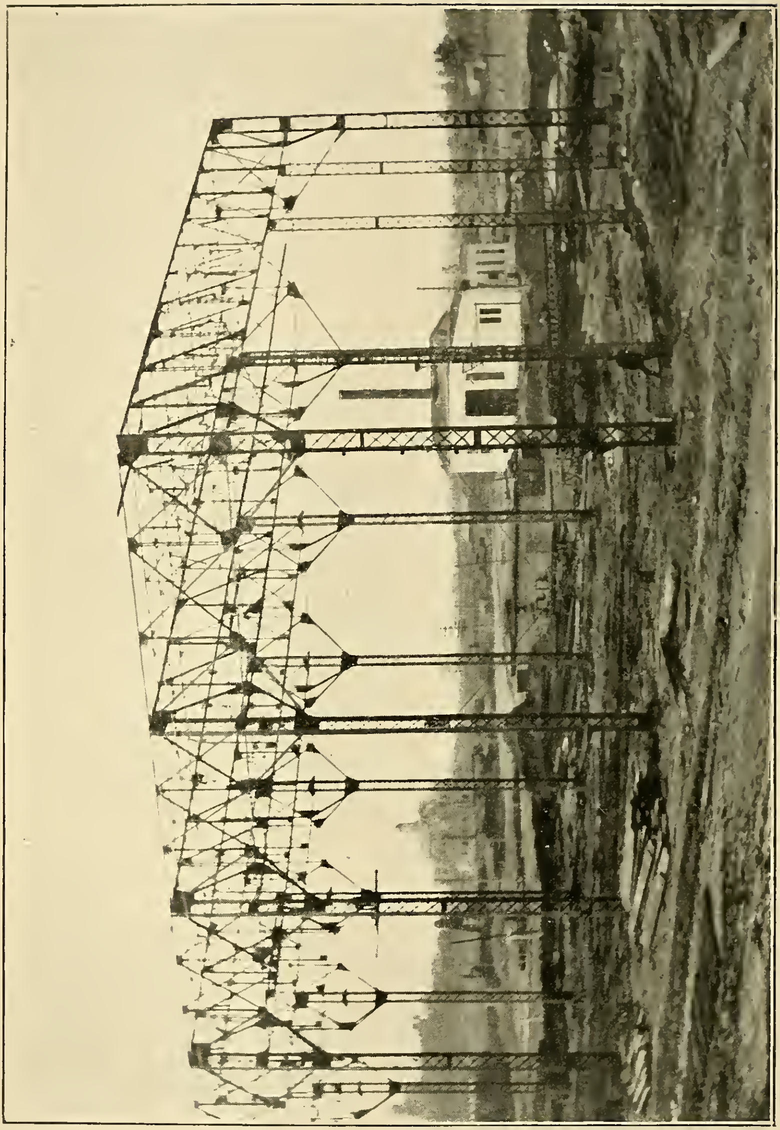
Time permitting, it would doubtless be of interest to take up such points as the rust-preventive qualities of cement mortar in contact with steel, the study of concrete as a non-conductor of heat and as a preventive of electrolysis, etc., but I must hasten to suggest what I consider the most practical application of steel-concrete construction to local conditions. This I believe to be the steel-concrete wall.

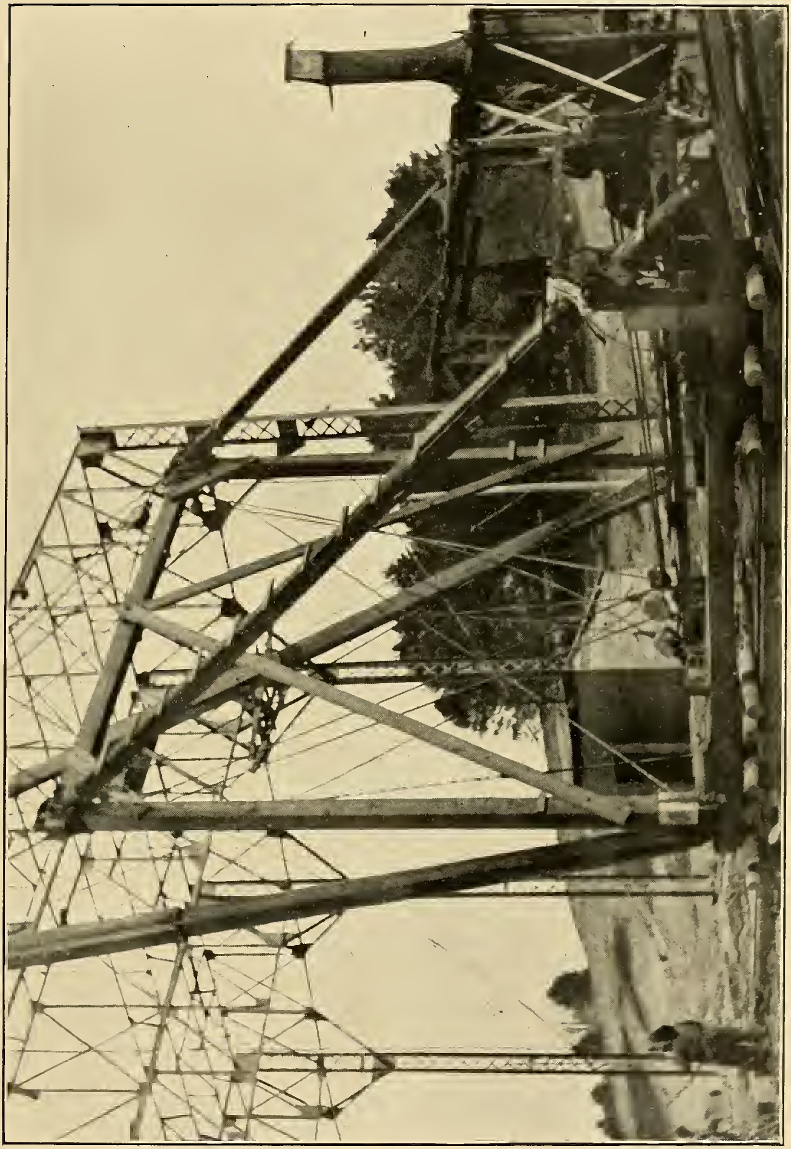
The peculiar soil of New Orleans and vicinity compels the engineer, when called upon to design a structure, to avoid, as much as possible, all heavy construction. In spite of this condition, I notice that, instead of using concrete, there are continually being built brick walls when a concrete wall would answer every purpose. Take, for example, a power house. We will say that the building

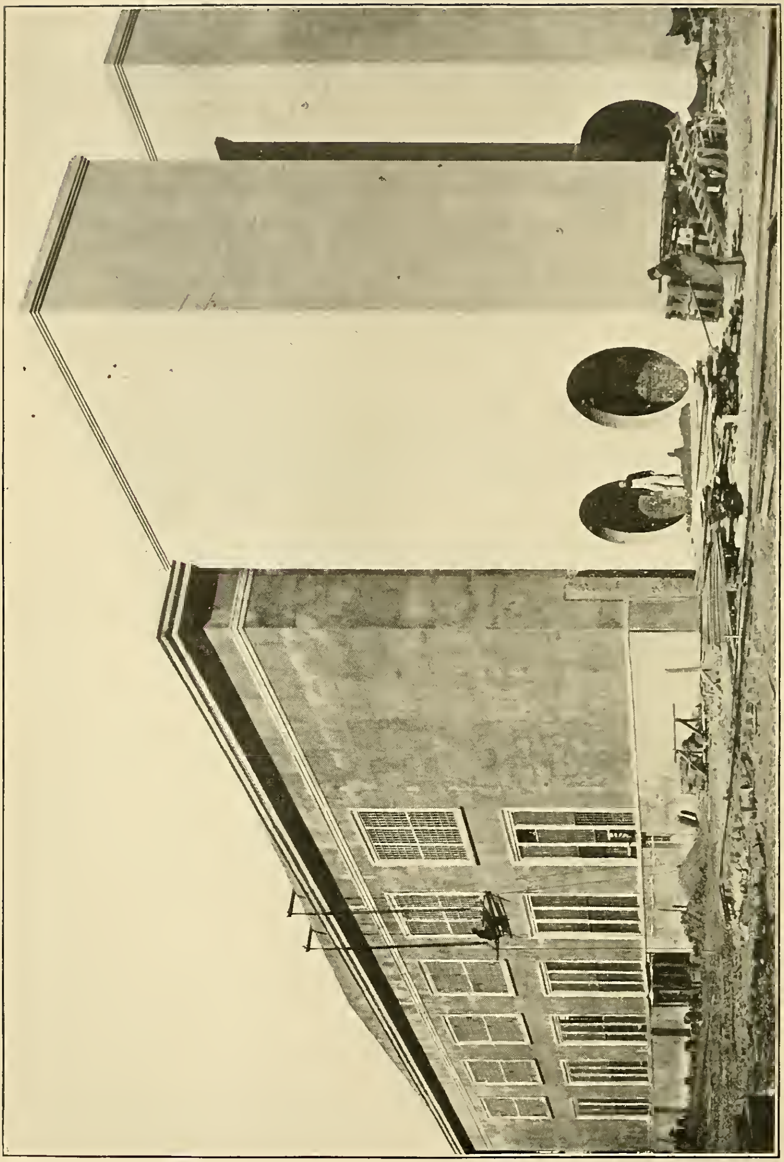












is 50 feet wide and 80 feet long, and that the walls are 30 feet high to the eaves. In brick construction this wall would be 22 inches thick, and the weight of the walls would therefore be about 800 tons. The same walls, of steel-concrete construction, could be built 6 inches thick. By supporting the roof on steel columns encased in concrete pilasters, equally good results would be obtained. The weight on the foundations would be 240 tons instead of 800 tons, and the cost to the owner would be about 10 per cent. less.

As an example of this sort of wall, I will call your attention to the boiler house at the Louisiana Purchase Exposition, St. Louis, Mo., which I assisted in designing. This building is about 200 feet by 300 feet, and the walls have a clear height of 40 feet from the floor to the bottom chord of the trusses. The steel columns are 20 feet apart, and the walls are built of cinder-concrete, reinforced with steel angles, channels and rods, and are but 6 inches thick. I present, for your inspection, some photographs showing the building during the erection of the steel work and others after the concrete wall was in place. These photographs were taken before the finish was applied to the exterior, and hence the rough appearance of the walls.

THE PURIFICATION OF WATER.

By Prof. John M. Ordway, Member of the Louisiana Engineering Society.

[Read before the Society, March 14, 1904.*]

Of the waters that are most readily available for use in the house or the factory, many fall short of a desirable degree of purity. Some contain suspended matter, some hold in solution salts of calcium, magnesium or iron, some are charged with colored or colorless organic substances as well as microscopic living organisms, and some have, at times, a slightly unpleasant odor or taste.

The coarse particles of solid matter, carried along by streams, are easily removed by filtration through sand; and the filter not infrequently takes out, from an apparently passable water, an astonishing amount of dirt. Indeed, leaving freshets out of account, there are very few rivers which are at all other times clear enough.

By very numerous experiments, made for the Massachusetts State Board of Health, it has been found that over 99 per cent. of the bacteria and other organisms which abound in surface waters may be removed by sand filtration. To be sure, most species of bacteria, diatoms, desmids and infusoria are not known to be harmful. Still, in thickly settled regions, typhoid and other disease-producing microbes are occasionally present in the water; and there are a few kinds of diatoms and infusoria which at times multiply inordinately and give the water a disagreeable odor or taste; so, on account of the occasional, unexpected occurrence of bad organisms, it is well to filter out all the removable living things. But when long enduring turbidity is caused by fine clay, it requires a filter of peculiar texture to do thorough work. A soft, porous earthenware burned at a moderate heat, appears to afford the most efficient apparatus. Thus, our very refractory Mississippi River water comes perfectly clear through an ordinary clay flower pot, though without pressure the rate is slow; such a pot, having an inner surface of 148 square inches, yielding 300 cubic centimeters in 24 hours.

There is now in the market a filter of similar material, called the "Lynn Filter," which, with a moderate pressure, does wonderfully well both as to quality and quantity. It consists of a hollow earthenware cylinder, arranged vertically in a strong cast-iron case, so that the turbid water has access to the inner and outer surfaces of the cylinder. Between these surfaces are many vertical tubular

* Manuscript received May 18, 1904.—Secretary, Ass'n of Eng. Socs.

passages, which receive the clear water and convey it to the outlet pipe at top. The mud is shaved off, from time to time, by bronze scrapers pushed hard by springs against the cylinder surfaces. These scrapers are set in frames, which are revolved by an outside crank with suitable gearing. The earthen cylinder, from which the piece shown was taken, was 15 inches in diameter on the inside, and 20 inches outside, and 29 inches long. The area of the cylinder surfaces was therefore 22 square feet. There were 32 tubular spaces in the wall, each $\frac{7}{8}$ inch in diameter, making an area of 17.7 square feet. The material is very soft, the necessarily frequent scrapings wear away the surfaces pretty fast, and, unless the springs are nicely adjusted, the wear is not uniform. So the cylinders, as well as the scrapers, must be replaced occasionally. The machine is expensive and requires careful management. Still, in some cases, it may be advisable to treat the Mississippi water in this way rather than by the coagulation method.

Color.—Many ponds, brooks and rivers are tinged, more or less, with organic matter derived from the soils which they drain. This brown matter, which goes under the general name of humic acid, is probably brought into solution by an exceedingly small amount of potash or soda, furnished by the gradual decomposition of the rock particles of the soil. It seems to be harmless, though it gives the water an unpleasant appearance.

The artesian water of our city, as seen at Tulane University, the Young Men's Gymnastic Club, the Central Power Station, and other localities, is very highly colored; and it may well be, for it contains about 37 parts of sodium carbonate to 100,000, and decayed vegetable remains abound in the depths of our delta.

But this water, bad looking as it is, can be completely decolorized in a few minutes by adding bibasic or tribasic aluminum chloride. Humic acid has a stronger affinity for alumina than for soda, and therefore a flocculent precipitate of aluminum humate is formed and rapidly subsides. Some costly attempts to clear this water by the use of alum and filtration have failed of success, because no skillful pains were taken to find out the exact amount of coagulant required. It is not a case of mere entanglement, but a definite chemical combination is to be formed, so that a certain amount of the base is needed, in order that it may unite with the whole of the humic acid present. With less alumina the precipitation is incomplete. It is really very easy, by a few intelligently conducted trials, to determine the proper quantity of the aluminum salt.

For decolorizing brown waters, the highly basic chloride of aluminum is much better than the ordinary sulphate, as it acts more

quickly; and, the needed alumina being combined with only one-half or one-third as much acid, much less alkali in the water will suffice to take up this acid and turn over the alumina to the undisputed possession of the humic acid. I have tried many surface waters of New England, Canada and Colorado, including the Connecticut, Merrimac and Androscoggin Rivers, and found that some forty of them were cleared by half a drop, a drop, or, in one or two instances, two drops of a 13 per cent. solution of the tribasic chloride to a liter of water. When the color is very faint, it takes several hours for the precipitate to gather and settle.

Iron.—Iron may be present in water as ferrous carbonate or sulphate. Of the carbonate we have a good instance here in New Orleans in the salt water of the deeper artesian well at the Young Men's Gymnastic Club. This water is perfectly clear and colorless as it comes from the ground, but in a very few minutes it becomes opaline, and after long exposure to the air it deposits the iron as insoluble ferric oxide. In the first method of fitting the water for bathing, we pumped it into 2 very large cisterns, and, after adding very small quantities of lime and aluminum sulphate, blew air through it for an hour or more. Then in a few hours it settled perfectly and permanently clear.

In a plan afterward adopted, the crude water was simply showered through the air in a very much broken fall, and then filtered through sand.

So, when iron is not obstinately held in solution by organic matter, we may readily bring about the change to insoluble peroxide by forcing air through the water, or by a much retarded dropping of the water through the air. The addition of a little lime or soda facilitates the oxidation. Such an addition is particularly needed when ferrous sulphate is present, since this salt is changed very slowly by the air, but when the stronger acid is taken up by an alkali there is formed ferrous oxide, which is very greedy of oxygen.

Hardness.—But the most common and most troublesome fault is the presence of lime and magnesia salts, which cause a harsh feeling in washing with soap, because they form sticky oleostearates of calcium and magnesium. We therefore call such waters "hard." The water of the Great Lakes and of the St. Lawrence River, which drains them, and that of most of our Western and Southern streams, is unpleasantly hard. In analyzing the Mississippi River water every week for a year, I found an average of 6.95 parts of calcium carbonate and 1.9 parts of magnesium carbonate in 100,000 parts of the settled water. The maximum amount of the

two together was 13.66, and the minimum 6.86. In a former paper on the water supply of New Orleans, I stated that the Mississippi River water contains carbonate of sodium. Later experiments have led me to believe that the sodium is present only as sulphate and chloride. The mud also contains some of the same substances.

After considering the best way to get rid of the mud, it seemed very desirable to go farther and find some feasible means of eliminating the soap-killing impurities. I have, therefore, made numerous experiments with such possible precipitants as are cheap enough and safe.

When we wish to know just what is thrown down by any chemical in a gradatory series of experiments, it is, of course, necessary to collect and analyze the precipitates—a work requiring much time and patience. But a ready means of forming a judgment as to the comparative efficiency of the trials is afforded by Clark's soap test, which consists in adding, to 100 cubic centimeters of the treated water, a standard solution of soap, a little at a time, till, on thorough shaking, a permanent foam remains on the surface. According to the French mode of reckoning, which is preferable to the English or German, the number of degrees of hardness is supposed to represent the number of grams of calcium carbonate in 100,000 c.c. of the water. The method does not admit of great precision, but it serves well for comparisons.

To give some idea of the possible ranges, I may state some of the results which I have obtained while going about during the summer vacations. The best of the waters tried was that of Peabody River at Gorham, N. H., a small stream a few miles long, which takes its rise among the highest of the White Mountains, where granite constitutes the geological formation. The hardness was much less than 1 degree. The water supply of Colorado Springs, coming from streams among the Rocky Mountains, had a hardness of somewhat less than 1 degree. Boston water, taken from the Chestnut Hill reservoir, showed 1.2 degrees, the same as the water supply of Quebec. That of Buffalo, N. Y., which comes from Lake Erie, stood at 7.6 degrees. The River St. Lawrence, at Montreal, gave 8.2 degrees. What was in use at St. Louis last July tested 9 degrees. At Denver, the average of two trials, a week apart, was 9.5 degrees.

Remarkable differences, within a moderate compass, were shown at a place among the Green Mountains, in a mica slate formation. A well on the high ridge of Randolph Centre showed a hardness of 21 degrees. Another well, some 80 rods away, tested 15 de-

grees. A copious spring, about 200 rods from the latter, and some 300 or 400 feet lower, showed 9.5 degrees.

In working with our river water, in order to have a stock of uniform composition and free from the interference of suspended clay, about 70 gallons of the crude water were run into a galvanized iron tank, and cleared by treatment with bibasic chloride of aluminum and iron. This was done last November, when the water contained about the maximum of dissolved impurities.

Two or four liters of clarified water were taken for each trial. Of the precipitants, the limewater contained 1 gram of lime in about 800. Of the others, normal solutions were made, like those used in volumetric analysis. That is, the soda salts, for instance, had 23 parts of sodium to a liter.

Lime.—Water which contains calcium and magnesium carbonates held in solution by carbonic acid may be partially purified by treating it with just enough limewater or milk of lime to combine with the excess of carbonic acid. The lime added is all precipitated, and with it a part of the carbonates originally present. As lime is a stronger base than magnesia, it may be expected to decompose the magnesium salts, and set the base free, but of the calcium compounds it can affect only the bicarbonate.

In my clarified water, one-fifth of the calcium carbonate had been changed to chloride by the coagulant used. About three-fifths of the remaining carbonate and one-sixth of the magnesia were thrown down by an optimum of 50 c.c. of limewater to a liter. The hardness was reduced from 10 degrees to 6.5 degrees.

With the softer water of February, cleared by the Lynn Filter, an optimum of 70 c.c. of limewater to a liter reduced the hardness from 7.5 degrees to 4.5 degrees.

So lime makes an improvement, but does not carry the softening quite far enough. Lime acts slowly, but the precipitation is completed in 24 hours.

Carbonate of Sodium.—When calcium sulphate is the offending substance—and it occurs in a great many waters—soda ash is a very suitable purifier, as it decomposes gypsum and leaves in solution harmless sodium sulphate, calcium carbonate being thrown down. But I hardly expected sodium carbonate to have any effect on calcium bicarbonate. In fact, however, it has a pretty strong affinity for carbonic acid, and when it was put into the clarified water it made no show for some time, though in a day or two there appeared a granular coating on the sides and bottom of the containing vessel. The maximum effect was produced by 6 c.c. of the nor-

mal soda solution to a liter, which precipitated most of the lime and reduced the hardness from 10 degrees to 4.5 degrees.

Carbonate of sodium, then, is slow in its action, and is somewhat lacking in efficiency.

Trisodic Phosphate.—This salt, which is made by combining caustic soda with the ordinary disodic phosphate, works much better than the carbonate, but it is somewhat more expensive. It precipitates both lime and magnesia as flocculent, somewhat gelatinous phosphates which settle readily.

In the clarified water of November, 6 c.c. of the normal solution threw down nearly three-fourths of the 2 carbonates, and brought the hardness down to 3.4 degrees.

From the softer water of last April, 6 c.c. took out nearly all the lime and magnesia and lowered the hardness to 1.6 degrees.

Caustic Soda.—Caustic soda proved to be the most effective of all the single purifiers. The precipitate formed by it is of a slightly gelatinous character, and is deposited in a few hours. The maximum effect on the clarified water was produced by 6 c.c. to a liter. By this amount nearly all the lime and magnesia were taken out and the hardness became less than 1 degree. With 5 c.c. to a liter, the hardness was diminished to 1.8 degrees, and this is soft enough for any use. The same quantities gave almost as good results with crude river water.

The precipitate produced by the caustic soda has some entrapping power, so that this alkali tends to clarify, as well as soften, the turbid water. But the gelatinous calcium and magnesium phosphates take a stronger hold on the fine clay, and hence the caustic operates more quickly when it has some trisodic phosphate mixed with it.

The turbid water, with 4 c.c. of caustic soda and 2 c.c. of the phosphate added to every liter, deposited the mud very quickly and became quite clear in less than 24 hours. Its hardness was then only 1.8 degrees.

For mere clarification, this alkaline coagulant cannot compete with aluminum and ferric salts, because a much larger quantity is required, and besides, if there is any organic matter present, a little more of it is left in solution. But for clearing and softening we may advantageously use both, putting in the soda mixture first and the aluminum or ferric salt awhile afterward, and leaving the water so treated 24 hours to settle.

Aluminate of Sodium.—As alumina is best for entrapping the mud, while soda is best for softening, it was thought that aluminate of sodium, which can be made very cheaply, might be the ideal

purifier. It was found to do the work, indeed, but altogether too slowly.

Double Oxalate of Sodium and Aluminum.—As in chemical analysis we find an oxalate to be the best precipitant of lime, it seemed that the oxalate of aluminum and sodium might produce the desirable double effect. But here again too much time is required for completing the reactions and settling. Moreover, the cost would be somewhat higher than that of the other articles mentioned.*

At first thought it seemed strange that, in order to effect the maximum amount of precipitation, there should be required an excess of the precipitant of one-half or more over and above what theory calls for. But, in such exceedingly weak solutions as the water under consideration, the salts are more or less dissociated into their constituents, and to counteract this there must be an excess, in some cases of the basic, and in others of the acid ingredient. Thus, in analytical work, to bring about a complete formation and precipitation of ammonio-phosphate of magnesium, we must use a considerable excess of ammonia; and, in trying our water with oxalic acid, it was found that 1.5 c.c. of the normal acid to a liter threw down about half of the lime, and reduced the hardness from 7.5 degrees to 3.7 degrees, while 3 c.c. increased the precipitate one-fifth, but was so much in excess as to carry the hardness up to 16 degrees.

Among the reagents used, only the lime, the alumina, the phosphoric acid and the oxalic acid are removed with the precipitates formed. The alkali of the sodium compounds remains in solution as bicarbonate, carbonate, and a little caustic. For most uses this small quantity of soda is unobjectionable, it being equivalent to not over 3 parts of sodium carbonate in 10,000, or 18 grains in a gallon. The alkalinity can be reduced by neutralizing one-third or one-half with any acid, after the water is settled and drawn off. But this complicates matters too much. Our artesian well water contains nearly 4 parts of sodium carbonate in 10,000, and this is certainly very good for steam boilers, at least.

* I have not dwelt particularly on the various combinations of the different chemicals that may be made. But it is obvious that advantages may be gained by using more than one. Thus, some of the turbid water was treated with 25 c.c. of limewater and 2 c.c. of caustic soda to a liter, and after a time, 0.45 c.c. of the bibasic ferric-aluminous chloride were added. In 4 hours it became pretty clear, and the hardness was 2.1 degrees. Of course, when lime and soda are used, in place of soda alone, the cost is less, and the water is left soft enough and much less alkaline.

But everybody cannot have an artesian well; and yet everybody who uses steam ought to have water that is as good or better. If such is lacking, it is very important to consider how the deficiency may be remedied. When lime and magnesia are the chief impurities, they can be mostly eliminated at a moderate cost, and thus there will be effected a saving of fuel and a saving of boilers.

A great many preventives and remedies have been empirically proposed for boiler incrustation, not a few of them being worse than useless. I believe the only articles that are rationally advantageous are caustic soda and lime for waters charged with the earthy carbonates, sodium carbonate for those containing the sulphates or chlorides, and trisodic phosphate for such as are turbid; and they should be used so as to take out the obnoxious substances before the water goes to the boilers. Prevention is far better than cure. We find accounts of several forms of apparatus which have been devised for the continuous separation of the impurities. In the most feasible ones, the water, after receiving the precipitant, is forced upward, in a slow current, against a series of deflectors, which are expected to turn aside the precipitate and let the clear water pass on. Of course, the real efficiency of such contrivances can be determined only by careful experiments. But it takes some little time for the reaction of the chemicals to be completed, and we should be surer of the best results if we let the treated water remain at perfect rest for several hours. I should, therefore, much prefer two or more simple settling tanks of sufficient size to furnish a full supply when used alternately.

For work on a moderate scale, as for domestic use, vessels like the one that I had made for my experiments would afford very good service. This is a galvanized iron cylinder 2 feet in diameter and 3 feet high, with a conical bottom 9 inches deep. It should have been 12 inches deep. About 3 inches above the outlet of the inverted cone is soldered to the sides a brass cross bar, perforated to receive the pivot of a $\frac{3}{4}$-inch vertical shaft. The shaft at top passes through the fixed middle piece of the wooden cover, and a little above this is furnished with a crank turning horizontally. Just above the lower brass bar there is fastened a piece of 2 x 3-inch joist, cut so as to form two propeller blades. A little brisk turning of the crank mixes thoroughly the crude water and the chemicals. The clear water is drawn off by a faucet close to the bottom, and the mud can be run out by a cock at the apex of the cone. As it is not best to fill the cylinder higher than to within 2 inches of the top, we may reckon on a yield of about 33 inches or 65 gallons for one operation. When the river is but moderately

turbid, the mud needs to be disposed of only after the third or fourth filling.

Probably a tank, 3 feet in diameter and 3 feet deep, would be strong enough, if made of galvanized iron simply locked and soldered and wired at top. Such a one would give 145 gallons at a time. In very large apparatus the stirring would be done better by blowing in air at the bottom.

As it costs more to soften than to clarify water, we cannot expect the city water supply to be brought to the highest attainable excellence. Yet, when a coagulant is used, the addition of a little lime, to reduce the hardness somewhat, would not increase the expense very materially. But individuals could afford to complete the work on what they require for their own use. And there are cases in which it would not be unreasonable to demand, of those who serve the public, the fullest possible purification. Thus, in traveling on our Southern railroads, to one who is accustomed to clean and soft water, it is particularly disgusting to find the wash rooms of the sleeping cars provided with water that is both hard and turbid. Surely, we pay enough for accommodations to justify a call for something better.

When our city is supplied with clarified river water, will the present cumbrous cisterns be needed?

For washing or cooking, good rain water is certainly far better than the filtered river water. But the rain water, gathered from city roofs, is quite different from rain water among the granite hills; especially when, as has been the case here for some months past, heavy, cleansing showers are few and far between. Lately I have found the hardness of my cistern water at home to be over 3 degrees. It contains sulphate of calcium, derived, no doubt, from fine coal ashes and soot carried up chimney by the draught and dropped on the rough, slated roof. Still it causes no harsh feeling in washing with soap. We may perhaps consider 4 degrees the limit below which water begins to be passably soft.

Very likely many householders will continue to use their cisterns as long as they last; then, instead of renewal, they may find it better to set up more compact softening apparatus and be no longer dependent upon the unreliable clouds.

BOILER AND ENGINE TEST OF A SMALL STEAMBOAT.

By Warren Johnson, Member of the Louisiana Engineering Society.

[Read before the Society, April 11, 1904.*]

The following data and results were obtained from a short test of 2 hours and 42 minutes duration, and are not intended to represent the greatest power or efficiency, but merely the average dynamic conditions obtaining in the usual operations of this screw-propelling towboat when used in regular service without tow.

The run was on the Mississippi River, following, as nearly as practicable, the same course up and down stream, to eliminate the effect of the current; starting and ending at the same point. All distances were obtained from the Orleans Levee Board.

SIZES AND DIMENSIONS.

WOODEN HULL.

Length over all	45 ft.
Length between perpendiculars	40 ft.
Beam, molded	9 ft. 6 in.
Draft amidships, to bottom of planking	1 ft. 11 in.
Displacement	23,860 lbs.
Block coefficient	52½ per cent.
Wetted surface	380 sq. ft.

BOILER.

No. 7 Roberts Water Tube Boiler:

Grate area	8.67 sq. ft.
Heating surface	264.3 sq.ft.
Ratio of grate to heating surface	1 to 30.5.
Nominal horse power for a compound engine	41.2.
Height of stack above grate	12 ft. 9 in.
Area of stack	1.4 sq. ft.
Ratio between area of grate and stack	6.2.

ENGINE.

Compound engine, with cylinders 5½ x 10½ x 8-inch stroke.
Cut-off in high-pressure cylinder 9-16 stroke.
Cut-off in low-pressure cylinder ⅞ stroke.
Clearance, in both cylinders, ¼ in. at each end.

CONDENSER.

Surface condenser, with an external tube area of 130 sq. ft.
Length of run of water through tubes, 9 ft.
Ratio between boiler heating surface and condensing surface, 2.04 to 1.

* Manuscript received May 18, 1904.—Secretary, Ass'n of Eng. Socs.

PUMPS.

Combined simplex air and circulating pump, 4½ x 5½ x 6.
Duplex feed pumps, 2 x 1⅛ x 2¾ in.

PROPELLER.

Brass screw propeller, 32 in. diam., 3½ ft. pitch, with total blade area of 3.6 sq. ft. on four blades.

Before starting, steam was raised to 100 pounds pressure, fires were drawn, and all water was pumped from condenser. When the boiler pressure had fallen to 40 pounds, fire was started anew with 27 pounds of yellow pine, and continued with Pittsburg coal, the analysis of which was given by the coal dealer as below, dried at 212° F.

Fixed carbon	63.02
Volatile matter	32.08
Ash	3.55
Moisture	1.35
	100.00

The coal is given a heat value of 15,120 B. T. U. per pound combustible, and the wood a value equal to half its weight in coal.

The fuel was weighed at start, and what was left unconsumed on grate and in ash pan was weighed and taken from original amount.

The heat necessary to raise 375 pounds of water (boiler capacity) from 40 pounds steam pressure to 152½ pounds average boiler pressure has been allowed in favor of the boiler efficiency. At no time was there any appreciable loss of steam by leaks.

The condensed steam was measured in buckets from start to finish, indicator cards were taken every 5 minutes for first half of trip and every 10 minutes thereafter on each cylinder.

The full boiler pressure never reached the high-pressure piston; a fact quite obvious on the cards and due to wire drawing through purposely cramped throttle.

Effort was rather successfully made to maintain uniform normal conditions throughout test.

Average steam pressure on boiler	152½ lbs.
Average revolutions	307 per min.
Average piston speed	409 ft. per min.
Average vacuum	20.65 in.
Average temperature of feed water	94¼° F.
Temperature of circulating water	42° F.
Temperature of atmosphere	65° F.
Mean pressure in high-pressure cylinder	55 lbs.
Mean pressure in low-pressure cylinder	7.47 lbs.
Mean effective pressure in high-pressure cylinder	47.53 lbs.
Mean effective pressure in low-pressure cylinder	2.80 lbs.

Average indicated horse power of high-pressure cylinder..	14.05
Average indicated horse power of low-pressure cylinder..	3.00
	——17.05
Total average indicated horse power......................	17.05

Total pounds of water evaporated from 94¼° F. feed water and at 152½ lbs. steam pressure.................................2,475

Total pounds of coal consumed.................................281.5

Making allowance for the heat units necessary to raise steam at 40 pounds to steam at 152½ pounds, and with feed water at an average temperature of 94¼° F., the efficiency of boiler was 82½ per cent.

Pounds of water evaporated per pound of coal, 8.8.

Pounds of coal burned per square foot of grate per hour, 12.1.

Pounds of water evaporated per hour per square foot of heating surface, 0.395.

Total steam consumed by engine, 71 per cent.

Total steam consumed by pumps, 29 per cent.

Thermal efficiency of engine, based on 2545 B. T. U. per horse power hour, 4.54 per cent. This low efficiency is partly due to the fact that there was no other duty on engine than propelling its own hull, also to a slightly undersized propeller and to a too great cut-off in high-pressure cylinder, necessitating a cramped throttle.

It is also important to note that, although the engine cylinders were covered with asbestos, the steam pipe from boiler to engine was exposed to a cold, stiff breeze and all pipes were uncovered; also that the engine was developing less than half its maximum horse power.

Total pounds of coal used per indicated horse power hour, 6.32.

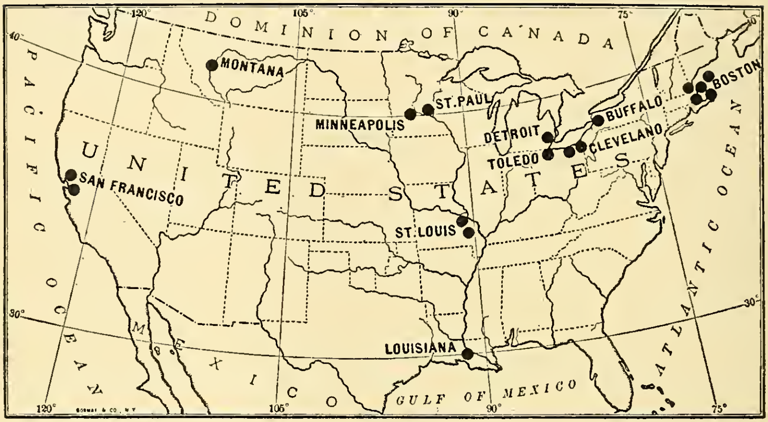
Total pounds of coal used for steam, through engine only, per indicated horse power hour, 4.50.

The total length of run was 22.8 miles or 19.8 knots in 2 hours and 36 minutes, a speed of 8.77 miles or 7.62 knots per hour.

The pitch travel of propeller was 12.2 miles per hour, a slip of 28.3 per cent.

We find that 4.46 indicated horse power was necessary per 100 square feet of wetted surface for a speed of 8.77 miles per hour, and, according to displacement, 0.714 horse power per hour was required for every 1000 pounds displacement. Although the hull has not fine lines, these values are fair.

On a previous trial, where speed was the object, 11⅓ miles per hour was maintained without trouble.



MAP

Showing the locations of the Societies forming

THE ASSOCIATION OF ENGINEERING SOCIETIES.

(Each dot represents a membership of one hundred, or fraction thereof over fifty.)

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIII. AUGUST, 1904. NO. 2.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

ORE-HANDLING PLANT AT THE CLAIRTON WORKS OF THE CRUCIBLE STEEL COMPANY.

BY CHAS. H. WRIGHT, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Civil Engineers' Club of Cleveland, January 12, 1904.*]

ALL I shall attempt to-night will be to briefly describe how ore, limestone and coke are conveyed from the railroad cars to the furnace.

There are about 330 blast furnaces in the United States. To feed these furnaces there are taken, from the Lake Superior region alone, approximately 20,000,000 tons of ore per year. Since the mines were first opened over 200,000,000 tons have been taken from this region. To handle one year's output would take a train of cars reaching from New York to Salt Lake City; and still the output is constantly increasing and new furnaces are going up on all sides. Whether some of them will not be a poor investment in a few years remains to be seen.

One of the largest of the plants recently built is that of the Crucible Steel Company, at Clairton, just above McKeesport, on the Monongahela River. The plant at present consists of twelve 50-ton open-hearth furnaces, but is laid out with a view to a doubling of this capacity in the future should the demand warrant it. There was also organized the St. Clair Furnace Company, operating three 450-ton blast furnaces. This plant also is laid out with a view to future enlargements. The new works are located on 170 acres of bottom land at Clairton. The question of size was very carefully considered, with a result that 450 tons per furnace was decided upon, in preference to stacks of larger capacity. The

* Manuscript received July 19, 1904.—Secretary, Ass'n of Eng. Socs.

mines, in which the company is interested, insure a supply of Mesaba ore, together with hard ores, for many years.

The blast-furnace plant at present consists of 3 stacks, 21 feet in diameter at the base by 85 feet in height, each stack being equipped with inclined skip hoists with electric hoisting engines. The stove equipment for each furnace consists of four 3-pass Massick and Crook's stoves, 21 feet in diameter by 95 feet in height. Blast is supplied to the furnaces by 7 cross-compound, condensing, steeple-type blowing engines, installed by the Southwark Foundry and Machine Company, of Philadelphia. Exhaust steam from the blowing engines is condensed by a 15,000 horse-power Weiss counter-current condenser. This condenser also handles the exhaust steam from all the auxiliary machinery, the pumping station and the electric power plant. Steam is supplied to the entire furnace plant by a battery of twelve 1000-horse-power Babcock and Wilcox boilers, the fuel being waste gas from the blast furnaces. The boilers also supply steam to the electric generating plant and to the pumping station.

Although the furnaces were designed for a capacity of 450 tons per day, they have actually produced more than this. One furnace, I believe, produced considerably more than 600 tons in 24 hours. This speaks well not only for the management, but also for the engineers who designed the furnaces. These men, by the way, were Cleveland men. One of them unfortunately did not live to see the successful completion of the plant. The machinery of the furnace hoist was built by the Otis Elevator Company, and the furnace top is of the double-bell type, as used by Julian Kennedy. There are at present 2 prominent types of furnace tops, one of them the 2-bell arrangement, and the other the rotating distributor type, as built by the Brown Hoisting Machinery Company. In the 2-bell arrangement there is a large lower bell and a smaller upper bell. As each skip-load of material is taken up to the furnace top it is dumped on the smaller or upper bell, which is then lowered, dropping the material on the large bell. After 4 or 5 skip-loads have been placed on the large bell in this manner it is lowered, and the material is dumped into the furnace. During the lowering of the large bell the small bell is closed, to prevent the escape of gas. In the rotating distributor system the large bell is used in practically the same manner as in the first arrangement, but, in place of the small upper bell, a rotating hopper and spout are used. This hopper is connected, by means of gears and shafting, with the large sheave around which the skip rope passes; and, every time the skip returns from the top of the furnace, it rotates this mechanism and turns the dis-

tributor through a portion of a circle. A ratchet arrangement, connected with this mechanism, is so arranged that, when the skip is going up to the top of the furnace, the ratchet simply slips by and the mechanism does not revolve, so that the hopper is rotated only by the return of the skip from the top; the weight of the skip car being more than sufficient to provide all the power necessary to rotate the hopper.

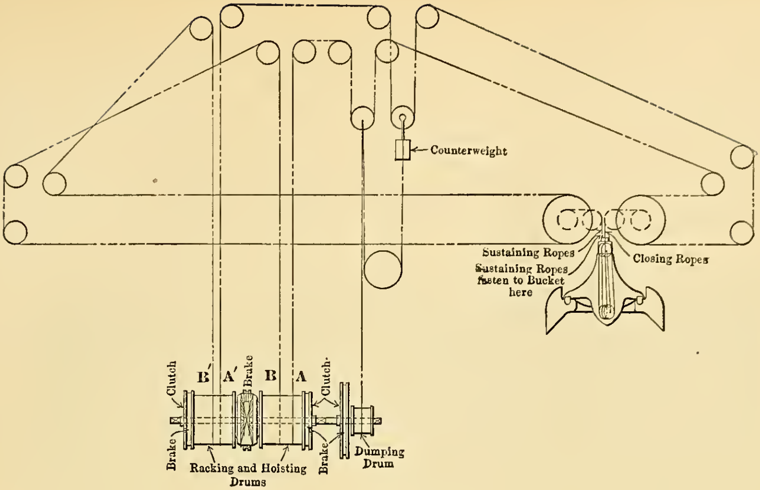
The angle through which the distributor moves at each trip depends upon the number of skip-loads which are used to make a load for the large bell. This is usually 4, and the distributor would turn through an angle of about 90°, a little more or a little less, so that no 2 successive revolutions would deposit the loads at the same points on the bell. The angle of rotation can be adjusted, and the material can be dumped at any desired point on the bell, and consequently placed at any desired point in the furnace. By this means a perfect distribution of the material can be obtained, not alone in theory, but also in practice. In the first tops which were built the distributor rested on 4 or 8 rollers, but this device was later replaced by a complete ring of balls about 3½ inches in diameter, resting in V-shaped grooves. Attached to the movable part of the hopper was a vertical lip which extended down into a trough attached to the fixed portion of the hopper. This trough was filled with sand, and, as the distributor rotated, this lip traveled around in the sand, the intention being to form a gas seal. It was found, however, that when the pressure reached a certain point or when there was a slight explosion, the sand would all be blown out and the seal ruined. This device, as well as the ball-bearing, is now replaced by a plain flat surface, on which the distributor rests. This surface is kept lubricated with powdered graphite and sometimes heavy oil, and is giving most excellent results, a perfect gas seal being formed and a simple means of rotation for the hopper provided. Attached to the hopper is a door, which is automatically closed whenever the bell is lowered, thus preventing the escape of gas. When the lower bell is closed the distributor door is always open, preventing the accumulation of gas in the upper part of the furnace top. Many furnace managers were rather skeptical when this top was introduced, as they claimed that a furnace top was the last place in the world where much mechanism should be placed, and that the extreme heat would soon warp and distort it, rendering it useless. Mr. Brown has demonstrated that, with proper care in design and protection for the mechanism, there need be no trouble from this cause; and it has run and will run for years, remaining in good condition.

The plant recently designed and constructed by the Brown Hoisting Machinery Company for the handling of material, ore, limestone and coke, at Clairton, consists briefly of the following items:

First. There is an electrically operated car dumper, which handles about thirty 60-ton cars per hour. The moving load, including the car itself, is 160,000 pounds. The material is dumped into a bin of 150 tons capacity, at the side of the tipple, from which bin it is drawn by means of spouts and gates, operated by a small motor, into bucket cars. The tipple is operated by two 130-horse-power motors, and is of the regular Brown type.

Second. The second item is a system of 6 electrically operated transfer cars and a suitable equipment of self-dumping tubs of $7\frac{1}{2}$ tons capacity. The transfer cars are arranged to run in pairs, each car being supplied with 35-horse-power motors, one car having a small cab, in which are placed the controller and mechanism for operating the cars. Each car carries 2 buckets. Current is supplied to the motors operating these cars by conductors of two $1\frac{1}{2}$-inch square wrought-iron bars. The current is taken from these conductors by means of sliding shoes at the end of an ordinary trolley arrangement. These transfer cars take the material from the bins at the tipple and transfer it to any convenient point along the front of the yard, from which the buckets are picked up by the bridge, and the material is dumped either on the stock pile or into the storage bins.

Third. There are two of the Brown patent traveling electric bridge tramways, having a span of 300 feet, a cantilever extension of 46 feet over the bins and a short extension at the pier, the extreme length of the bridge being 369 feet. Two 130-horse-power motors are provided for each bridge, and 1 operator controls all the movements of the buckets and the trolley, and the travel of the bridge itself along the yard. The moving load on the bridge is 24,500 pounds, and the engines are designed to move this load along the bridge at a rate of 1000 feet per minute and to hoist the bucket at 350 feet per minute. The travel of the crane itself along the tracks is about 75 feet per minute. The bridges are designed to handle $7\frac{1}{2}$-ton stocking tubs, or to take material from the stock pile and deposit it in the storage bins by means of $7\frac{1}{2}$-ton shovel buckets or 5-ton 2-rope grab buckets. The bridge operates on what is known as the rope system; that is, the movements of the buckets and of the trolley are controlled by ropes running from the trolley across the bridge and down the pier to the drums in the engine house. During the last year or two there has been a tendency to replace this rope


Counterweight
Sustaining Ropes
Sustaining Ropes fasten to Bucket here
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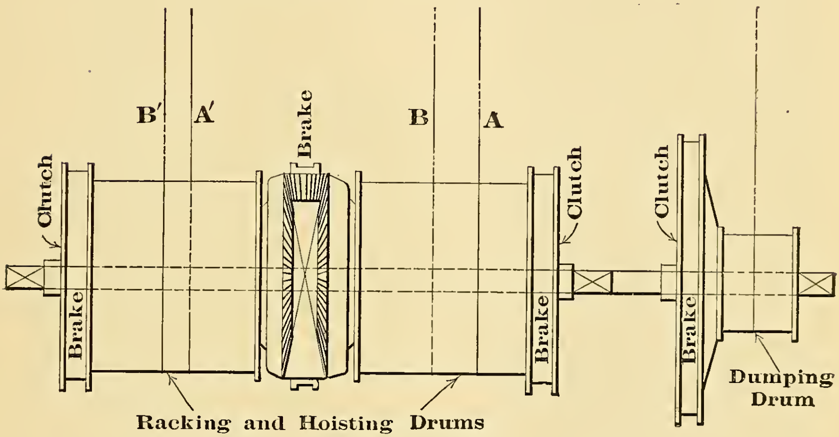
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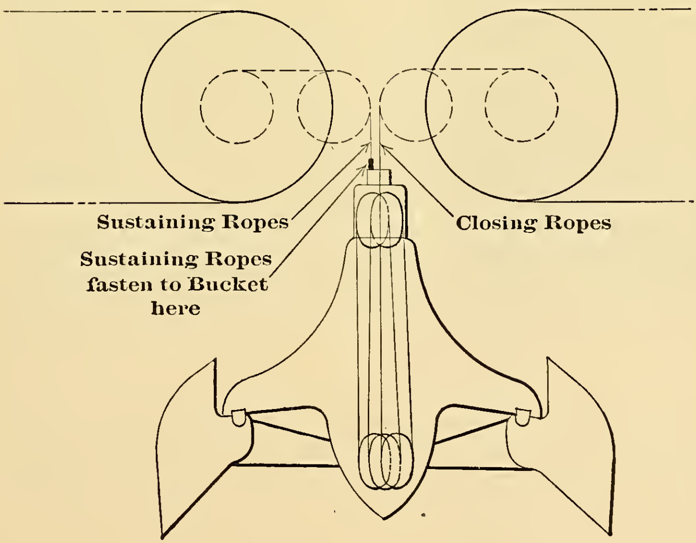
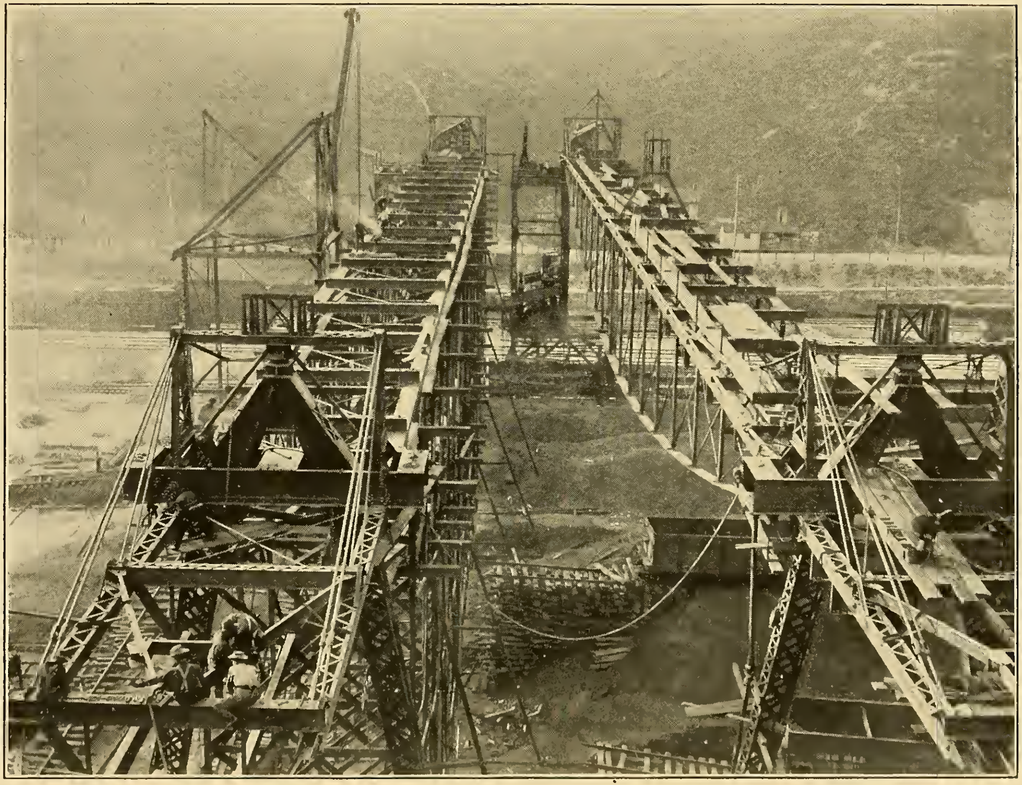

Sustaining Ropes
Closing Ropes
Sustaining Ropes fasten to Bucket here

system by what is known as the man trolley arrangement. With the man trolley plan the operator rides on the trolley, and all the mechanism for operating the buckets and the trolley is also placed on the trolley. The first advantage of this plan is that the operator is always at the point where he is working, and can see exactly what is being done. The second advantage is that a large percentage of the ropes and expensive sheaves, bearings and supports are dispensed with. On the bridges at Clairton there are approximately $2\frac{1}{2}$ miles of rope on each machine. These ropes and their supports are, of course, an expensive item to install and keep in repair. An objection to the man trolley system is the fact that the moving loads of the structure are increased from 2 to $2\frac{1}{2}$ times over those where the rope system is used, and a very much heavier structure is necessary. There are many points which could be mentioned in favor of both systems. The Brown Hoisting Machinery Company has a large number of both types in operation.

During the last two or three years many have been working to design a grab bucket which would successfully handle ore. A bucket may handle coal very successfully, and yet a bucket built on the same lines may be a perfect failure when it is attempted to use it in ore. Some of the first buckets designed to handle ore were arranged to work on the same principle as the orange peel bucket used in dredging. This was not a success, and later buckets have been designed to act first as a scraper, scraping together a load of ore and then picking it up. There are several buckets now on the market doing successful work. The Brown Hoisting Machinery Company has just completed a bucket which bids fair to prove very satisfactory. The Hulett people have a good bucket, and the Mason & Hoover Company has a bucket which does most astonishing things. The first time I saw the bucket in operation I could explain how the operator was able to do what he did with it only on the ground that it was a practical application of the principles of Christian science. The bucket hung from the trolley by 3 or 4 ropes, and it seemed as though about all the operator could do was to open and close the bucket. I actually saw him make the bucket walk along a pile, stand up on one corner, pull a load of ore out of the side of a pile and turn over on its side; swing around under the hatches of a boat and scrape out a full bucket of ore. I should say this bucket would take 95 per cent. of the ore out of an ordinary boat.

There are two types of grab buckets, known as the 2-rope and single-rope types. In the 2-rope system there is a set of lines attached to the shell of the bucket, and the second set is attached to



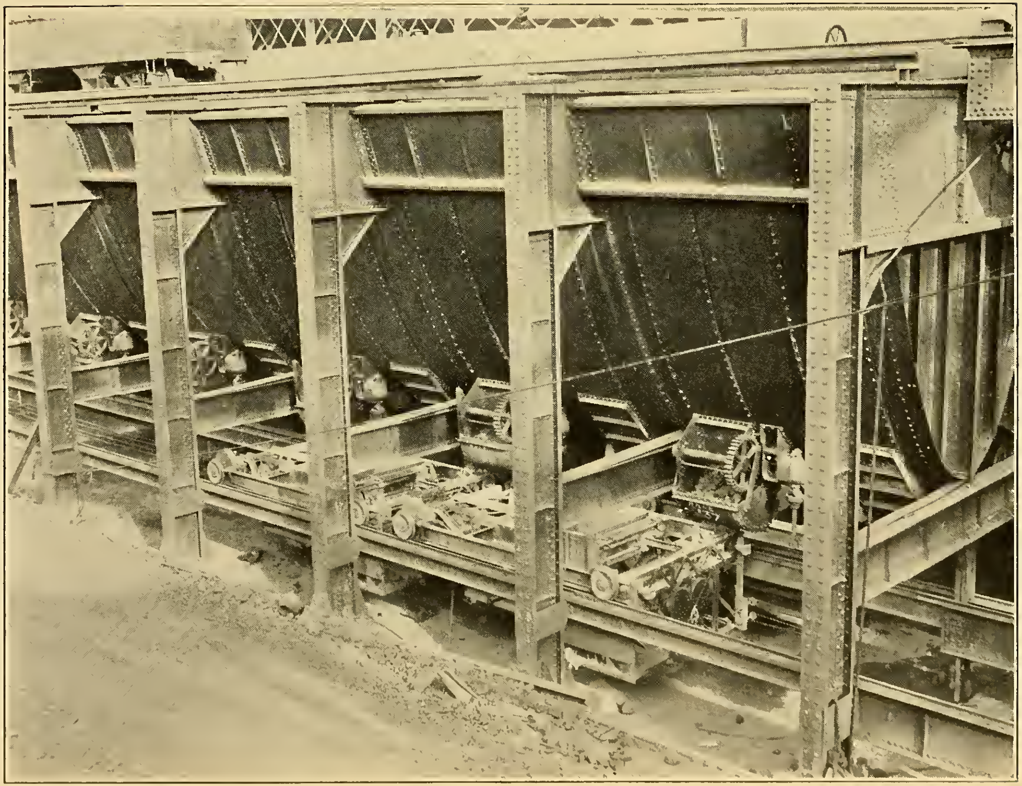
Ore-Handling Bridges in Process of Erection, Showing Erecting Traveler and Construction Work in Detail.

General View of Bins and Furnaces at Clairton.

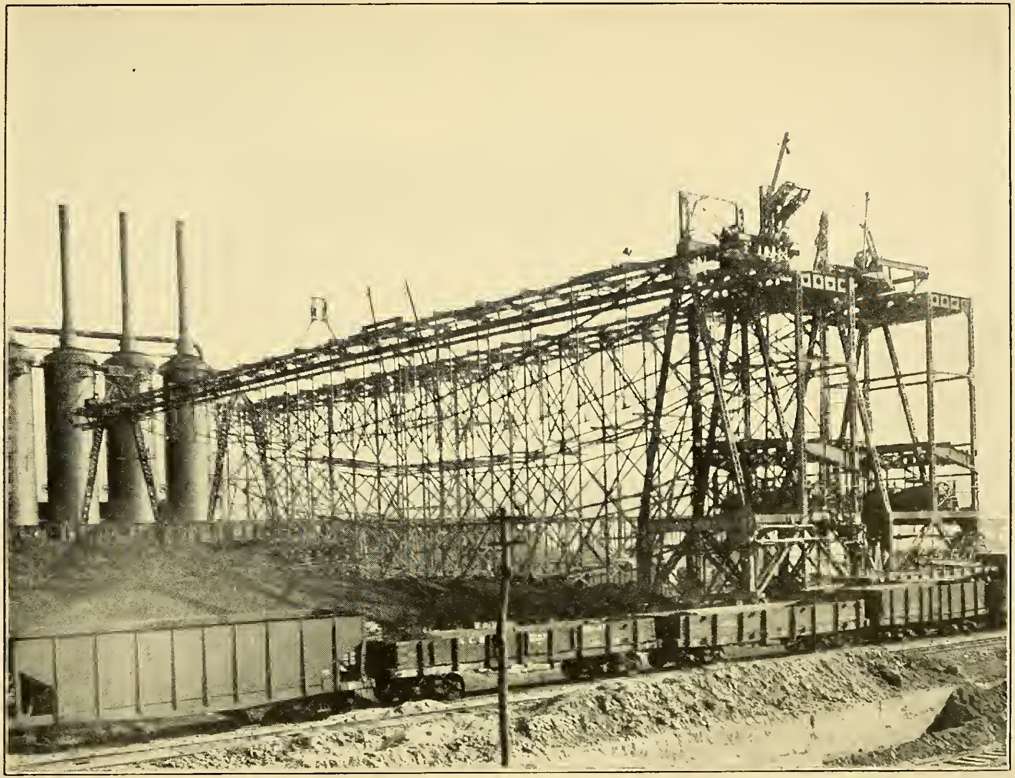
the blades by means of sheaves and suitable mechanism. By pulling up on the lines which are attached to the blades a load of ore is taken up, and the bucket is carried on these lines to the point where it is to be dumped; the load is then thrown over on the lines which are attached to the shell, and, by releasing the closing lines, the bucket is opened and the load is dumped. In the single-rope system there is no line attached directly to the shell, and, for most of these buckets, a second man is required to release the blades when the bucket has been opened or to adjust the mechanism for closing the bucket again. Mr. Brown has recently perfected and put on the market a single-rope bucket which does away with this extra man. With this bucket he is able to perform everything that can be done with a 2-rope bucket and only 1 man is required to operate it. When the bucket is to be dumped it is raised to the trolley, and the trolley is moved to the point where the bucket is to be dumped. The bucket then strikes a trapeze, which releases the mechanism attached to the blades, and the bucket opens. As the bucket is lowered on the ore again, this mechanism is automatically attached to the blades and the bucket is ready to close and to go through the operation a second time. A great advantage of this bucket is that, with very little change, it can be attached to the machines now in use, and will make these old rigs practically as valuable as the 2-rope machines. There is a large demand for these buckets, and the number which will be sold seems to depend largely upon the ability of the shop to turn them out. One of the most serious difficulties with which the makers of ore-handling machinery have to contend is the difficulty of reaching the ore between the hatches of a boat. It has been necessary to keep a gang of shovelers moving this material out under the hatches where the buckets can reach it. This difficulty has been overcome by the great Hulett machines, working at Conneaut, Buffalo and other places, by attaching the bucket to a vertical arm which rotates and also has a side motion, allowing it to carry the bucket underneath the framing between the hatches. This plan has been very successful in its work, and has made its designer justly famous. In some machinery which Mr. Brown is now building for Conneaut Harbor, he proposes to reach the material between the hatches by having the trolley suspended from a turntable. By rotating the turntable the bucket can be swung around after it has gone through the hatch, so that it can reach the material between the hatches. The spread of the bucket is made sufficient to reach from one hatch halfway to the next, so that practically all the material in the boat can be reached by this mechanism without scraping to the hatches. If the machine is as

successful as it seems likely to be, it will furnish a comparatively cheap machine, which will remove practically all the ore from a boat without the aid of hand-shovelers.

Fourth. There is a system of storage bins about 710 feet in length. These bins are arranged in a double line, one line being used for the storage of ore and limestone, and the second line for the storage of coke. The ore bins are of the parabolic suspension type, and have a capacity of 13½ tons of ore per lineal foot. The coke bins are in the form of a half parabola, one side of the ore bin also forming one side of the coke bin, effecting a considerable saving in material. The bins are divided into pockets of about 14 feet each. Of the pockets nearest the furnace, as many as necessary are reserved for the storage of limestone. There are 2 lines of railroad tracks on top of the bins, and all the coke is brought up on top of the bins and dumped directly from the cars into the pockets. The ore and limestone can also be dumped directly from the cars if this is desired. The sides of the bins are usually protected by either wooden or brick walls, to prevent the ore from freezing in the winter. In some bins now being built at Buffalo, the shell of the ore bin is made double, with an air space, and it is the intention to pump hot air into this space, and in this manner prevent the ore from freezing. The ore is drawn from the bottom of the bins into the larry. Underneath the bins are 2 tracks on which these larries run. The spouts under the bins are arranged alternately, so that the ore can be drawn off into the larries on either track as desired. These spouts are usually operated by electric power. In the first bins built of these types hand power was used. This proved not to be very satisfactory, and at Rankin a steam cylinder about 8 x 10 inches was attached to each gate. This cylinder, I understand, has worked very satisfactorily. Considerable care is, of course, necessary to prevent the freezing of pipes in cold weather. In other bins a longitudinal shaft has been used, running the full length of the bins and operated by motors, the mechanism at each gate being connected to the shaft by means of a jaw coupling. The controlling mechanism is also so arranged that the operator, at any gate, can start and stop the motor, so that the motor runs only while the gate is being used. In some of the later bins, the motor for operating the gates and most of the mechanism has been placed on the larry, this mechanism being connected to the portion which is fixed to the gate by means of a male and female coupling, which is thrown into mesh by means of a foot lever. This is the most satisfactory arrangement which has yet been installed for operating the gates. The gates of the coke bin are operated like those on the ore bins,



Ore Bins and Larries at Clairton Steel Co.'s Plant.



Ore-Handling Bridges at Clairton in Process of Erection.

except that hand power is used, as these gates work much easier than those on the ore and limestone bins.

Fifth. The fifth item is the larry equipment for transferring the material from the storage bins to the skip-car, by means of which it is taken to the top of the furnace. The tracks on which these larries run are sometimes suspended from the bins, an I-beam being used for the tracks and the wheels of the larry running on the flanges. In other cases, I-beams or girders, with a railroad rail on top, are used, and in this case the track is placed 4 feet above the ground. In some cases the suspended track is preferable, and in some cases the regular rail construction is better.

There are 6 ore larries and 3 coke larries at Clairton. The coke larries are coupled to 3 of the ore larries, running on the same track, 1 operator handling both the ore and coke larries. The ore larries have a capacity of 75 cubic feet and the coke larries a capacity of 120 cubic feet. On the ore larries there are scales for weighing the ore and limestone. The larries will run the full length of the bins, and can take material from any bin and load it into the skip at any furnace. Ordinarily there would be 2 ore larries and 1 coke larry at each furnace. Only 1 operator is required to draw the material from the bins into the larries. There are 2 small motors on each of the ore larries, one for operating the bin-gate mechanism and the other for moving the larry. Different types of these larries are in successful operation. At Rankin the locomotive was made independent of the larry, 1 locomotive hauling 3 or 4 larries if desired. At the Cleveland furnace the larry is made double, 1 frame containing 2 larry buckets and all the mechanism for traveling the larry. For a furnace in Alabama some larries were recently built in which hand power was used for moving the larries along the track, as it was only a short distance from the farthest bin to the furnace. These larries have been able to easily keep the furnace supplied with ore and limestone. At most furnaces the coke bins are so arranged that the material is drawn directly from the bins into the skip, by which it is taken to the top of the furnace, no larry being required for handling this material.

The weight of the car dumper at Clairton is about 650,000 pounds; the weight of each of the bridges is approximately 700,000 pounds. Each pair of transfer cars weighs approximately 30,000 pounds. The weight of the bins, complete, is in the neighborhood of 3,300,000 pounds, the weight of the larries about 16,000 pounds.

The general arrangement of the yard is as follows:

Next to the railroad tracks, which are on the side of the yard farthest from the line of furnaces, there is a storage yard of large

capacity for storing loaded cars, and also for the storage of the empty cars after they have left the car dumper. At the side of this storage yard next to the furnaces is a track on which the car dumper is placed. A system of switches enables the cars to be run in from any storage track onto the track leading to the tipple. The loaded cars, after they have been pushed down, either by locomotive or by gravity, to a point near the tipple, are pushed up an incline into the tipple by means of a "ground hog" or disappearing car, which runs into a pit below the track, enabling it to get out of the way of the loaded cars. After a car has been run into the tipple and dumped, the "ground hog" pulls another car up onto the incline and into the tipple, pushing the car just dumped out of the way, down an incline from the tipple, from which the car is automatically switched back into the storage yard for empty cars. Only 1 operator in the tipple is required to unload the cars and switch them back into the storage yard after they have once been run down to the point where they can be reached by the "ground hog."

The tracks for the transfer cars run along the yard parallel to the storage track, and are so arranged that the loaded cars, after leaving the storage bin at the tipple, are automatically switched back on the track underneath the pier of the bridge, and, when the buckets have been emptied by the bridge, the train of empty cars continues on down the track to the end of the storage space, and is then switched back onto the track which takes them underneath the bin again, the switches being so arranged that they are thrown automatically, no switchmen being required.

Between these transfer tracks and the storage bin at the furnaces is a space about 300 feet in width and 1000 feet in length, which is used for the storage of the various kinds of ore and limestone. This entire space can be covered by either bridge, so that if desired both bridges can be working upon the same kind of ore at the same time, or one bridge can be unloading ore onto the stock pile, while the second bridge is either loading ore from the transfer system into the bins direct or is taking ore from the stock pile and supplying the bins.

The runway tracks for the bridge tramways are arranged to straddle the bucket car tracks, the tipple being placed at one end of the yard, so that no crossings are required for the bucket car tracks over the crane tracks. In other words, the transfer cars never have to cross the tracks which carry the bridge tramways.

Only one operator in the house on each bridge tramway is required for the handling of either the dumping tubs, shovel bucket or grab bucket, and, when the bridges are using either the shovel

bucket or the grab bucket, only 1 man is required for the handling of the ore from the stock pile into the bins. When the transfer cars are being used, 2 men are required on each train of cars, to hook on and unhook the tubs, and a third man is usually employed to move and control the train of cars.

Allowed Stresses.

	Medium Steel.	Soft Steel.	Iron.
Tension—			
Live loads. Counters and similar members..	....	8,500	7,500
Live loads. Chords, girders and similar members	13,000	11,500	10,000
Live loads. Stringers and similar members..	13,000	11,500	10,000
[Subject to shock]	9,500	8,500	7,500
Dead and wind load........	16,500	14,500	12,500
Do not use stringers with thin web [provide ample stiffness.]			
Compression—			
Live load. Members subject to shock......	11,000	9,000	7,500
Live load. Members not subject to shock..	13,000	11,500	10,000
Dead and wind load........	16,500	14,500	12,500
Reduce by column formula when $\frac{\text{l in feet}}{\text{r in inches}}$ = more than 4.			
Shearing—			
Girder webs	9,000	7,500	6,000
Rivets, bolts and pins. [General]........	....	9,000	7,500
Rivets, bolts and pins. [In sheave supports].	....	8,000	6,000
Bearing—			
Rivets, bolts and pins. [General]........	....	18,000	15,000
Rivets, bolts and pins. [In sheave supports].	....	15,000	12,000
Bending—			
Rivets, bolts, pins and post ends. See sheet No. 25,580	....	18,000	15,000
Gas-pipe posts. See sheet No. 25,580.......	....	7,500	7,500
Axles of sheaves, hoist blocks, trolleys, etc..	....	15,000	12,000
Axles of truck wheels	....	15,000	12,000
Shafting—			
Bending. (Solid shaft)	15,000	12,000	10,000
Bending. (Pipe shaft)	....	7,500	7,500
Torsion. (Solid shaft)	12.000	10,000	8,000
Torsion. (Pipe shaft)	....	6,000	6,000
Shafts and axles over 5½ inches diameter to be of hammered steel.			

Journal Pressures—

For slow-running well-oiled bearing allow 1000 to 1200 pounds per square inch; for heavy loads or high speeds allow 400 to 800 pounds per square inch.

Gear Teeth—

Strain per square inch, cast iron or bronze, 3000 to 6500 pounds.
Strain per square inch, cast steel, 8,000 to 18,000 pounds, depending on service.
For spurs, add 4 per cent. for friction.
For bevels, add 8 per cent. for friction.
For worms, take efficiency at 40 per cent.

Note.—Do not use a steel worm with a steel worm wheel.

Wherever possible have sliding surfaces in contact of different material.
Figure no structure for a smaller moving load than 7000 pounds.
Where bent welded loops are used unit stress should not exceed 6000 to 7000 pounds.
Avoid eccentric stresses; make all, even unimportant, members meet at intersection of center lines.

Ultimate—

50,000, 58,000 and 66,000.

Comparative Table of Dimensions of American and British Blast Furnaces.

			American.	British
Height, feet			75 80 106	60 65 85
Hearth diameter, feet			11 11 15	10 10.5 11
Bosh diameter, feet			20 22 23	18.5 19 20
Internal capacity	cubic feet		14,600 19,800 26,500	10,012 12,610 18,495
	cubic feet per ton per diem		73 60 46	105 87 89
Output, tons per diem			200 330 570	95 145 206
Coke consumed, pounds per ton of iron			1,912 1,884 1,780	2,352 2,268 2,206
Blast	temperature, Fahrenheit		1,100 1,100 1,100	1,100 1,100 1,100
	pressure, pounds per square inch		5 10 15	5 6 7
	consumption	cubic feet per minute	16,000 25,000 50,000	9,540 13,500 17,263
		cubic feet per ton of iron	115,200 109,090 126,315	144,606 134,068 120,673

SPECIFICATIONS.

Specifications for one ore-handling plant, referred to in letter to the Crucible Steel Company of America, dated February 15, 1902, and consisting of car tipple, transfer cars, automatic self-dumping buckets, bridge tramways, shovel buckets, grab buckets; ore, limestone and coke bins; suspending trolley tracks, overhead railroad tracks connecting bins; ore and coke-bin chutes and gates; electric charging larries, and chutes for conducting material into skip-cars.

MATERIAL.

The various parts of the plant are to be built entirely of iron and steel, except the footways on top of the bridge tramways, doors, windows and floors of transfer cars, larries and operators' houses, which are to be of wood.

STRAINS.

All members of the said plant to be designed and constructed of ample strength for the loads to be carried.

The said plant to comprise:

CAR TIPPLE.

The car tipple is to be similar in construction and capacity to those furnished for the Carnegie Steel Company, at Rankin, Pa. It will be capable of handling open or gondola cars of the present standard dimensions up to 60 tons of maximum loads, including the weight of the car of 160,000 pounds; the contents of the car to be dumped into a bin having a capacity of about 100 tons.

From this bin the material is drawn off, by means of a special system of gates and mechanism, into buckets of 7½ tons capacity, resting on cars. When loaded, these buckets are conveyed, by means of these electrically driven cars carrying 2 buckets each, to such position as may be necessary for handling them by the bridge tramway.

STRUCTURE FRAME.

The structure consists in general of a rectangular frame, of such dimensions as to include the cradle and framework for holding and dumping the car. On top of the frame the engine house and operator's house are located, these houses being of sufficient size to give ample room for the machinery and for the operator to control the same. Framework is also provided for the support of the counterweight and its sheaves.

CRADLE.

The cradle consists of 2 U-shaped girders attached to the frame by the large pins around which they rotate. These girders are connected by longitudinal beams carrying the track and which form a system of bracing for the cradle. The cradle also forms a support for the various clamping devices. The motion of the cradle is controlled in part by the counterweight connected to it by a system of ropes and sheaves.

CLAMPING DEVICES.

The clamping device for holding the car will consist of 4 independent sets of clamps, which bear against the side and top of the cars. These clamps are so designed as to hold open cars of the present standard dimensions up to 60 tons capacity. The clamps are operated by a special hydraulic system of mechanism, pressure being obtained by a small independent motor.

COUNTERWEIGHT.

The counterweight, which partially controls the motion of the cradle, consists of a cylinder of sheet steel, and filled with ore or pig iron. The position of the counterweight is such that it is adjusted for the desired effect upon the cradle and its load.

DISAPPEARING CAR.

The "ground hog," which is used for hauling the loaded cars up the incline into the tipple, consists of a cylinder of sheet iron, filled with ore and resting on track wheels on rails between the standard gauge rails used by the cars. When not in use, the ground hog is lowered into the pit beneath the track, the motion being controlled by the operator in the tipple house.

ENGINE AND OPERATORS' HOUSES.

The engine and operators' houses to consist of a steel frame covered with corrugated iron sides and roof, provided with a sufficient number of windows to enable the operator to observe the entire operation of the plant, and will be provided with ladders and doors for entrance to same.

ENGINE.

(1) The engine to consist of sufficient drums and mechanism for hoisting and rotating the cradle.

(2) The drums, sheaves and mechanism for operating the disappearing car.

(3) The operating mechanism necessary for controlling the various functions of the machine.

ELECTRICAL EQUIPMENT.

Electrical equipment shall consist of two 130-horse-power Elwell Parker electric motors using 220 volts direct current; also such controllers, resistance boxes and wiring as may be necessary for operating and controlling the same.

HYDRAULIC EQUIPMENT.

Hydraulic equipment shall consist of 1 triplex pump, operated by an electric motor and provided with pressure regulating valve and the necessary tanks, accumulator, valves, piping and cylinders for operating the various clamps for holding the car while being dumped.

TUB TRANSFER CARS.

Six steel cars with oak platforms; 3 of the said cars to be equipped with motor, controller, resistance boxes, etc. Each of the steel cars to be large enough to carry 2 of the 7½-ton automatic dump buckets.

AUTOMATIC DUMP BUCKETS OR TUBS.

Fourteen of Brown's patent self-dumping ore tubs or buckets, of 7½ tons capacity each.

BRIDGE TRAMWAYS.

Two of Brown's patent trussed bridge tramways, each of 300 feet span, with cantilever at one end of 43 feet, and a tramway extension at the other end of 14 feet, making a total trolley travel of 341 feet, and a total length from end to end over all of 357 feet, and of the further general dimensions as indicated.

PIER.

Said bridge to be supported at one end of the span on 1 double-track pier and on the other end by a single-track pier and shear leg. The double-track pier is to be arranged to be mounted on parallel tracks, 28 feet center to center, and arranged to straddle 2 standard railroad tracks 12 feet center to center. The said single and double-track piers to be constructed entirely of iron and steel, mounted on chilled faced double-flanged track wheels, and provided with suitable and convenient moving gears to move them along the rails or tracks on which they are mounted.

MOVING GEAR.

The moving gear for each of the single and double-track piers to be arranged to be operated by power and controlled from the operator's house on the double-track pier.

AUTOMATIC SAFETY DOGS.

Each of the single piers is to be provided with a set of steel safety dogs, arranged to automatically drop onto the heads of the rails on which the pier is mounted when the bridge tramway is skewed in either direction from the center line to the allowable working limit.

PATENT SAFETY CLAMPS.

Each of the said piers is to be provided with a set of Brown's patent safety clamps, with safety jaws arranged so that they will always be under the head of the rail for securing the piers to the track when not being moved.

TROLLEY.

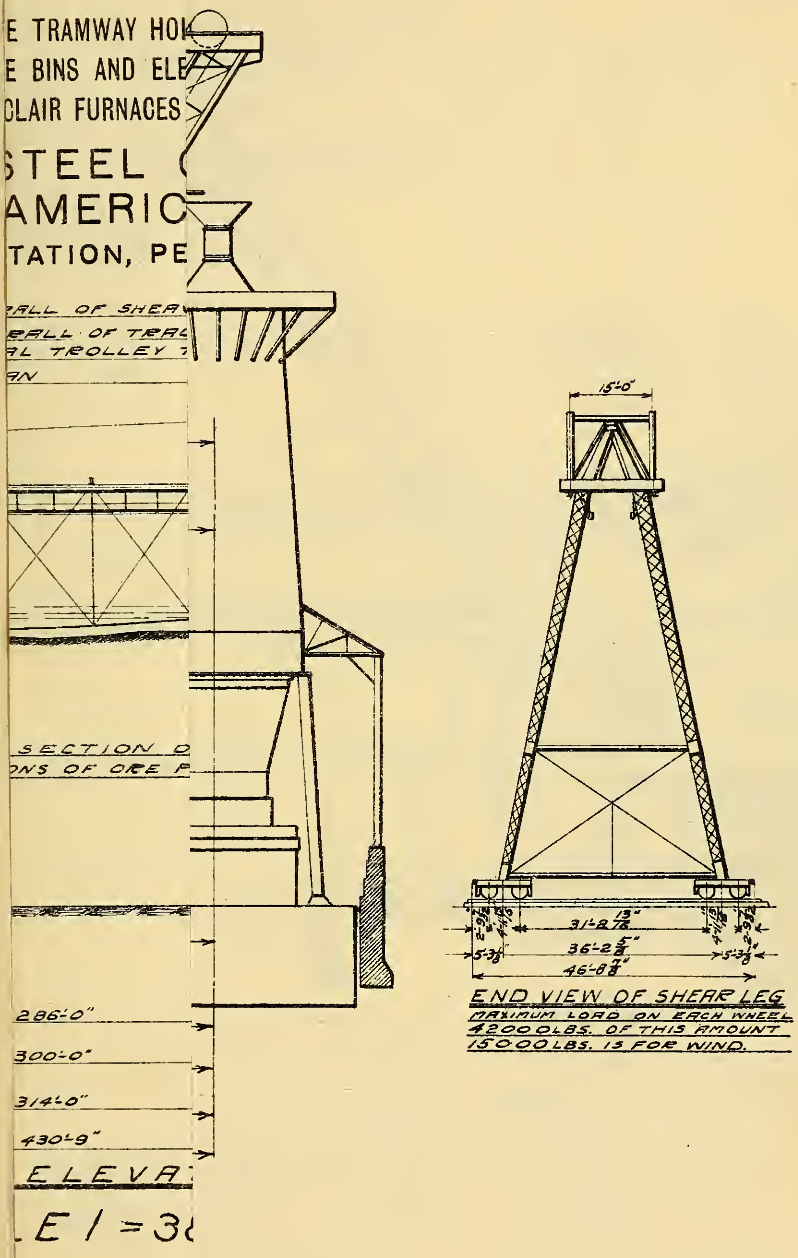
Each bridge to be supplied with 1 of Brown's patent hoisting and conveying machines, and all the necessary sheaves, pulleys and wire rope for the operation of either a shovel bucket or a 2-rope grab bucket.

CAPACITY.

Each of the said bridge tramways to be of sufficient capacity to handle 7½ gross tons of ore with either the automatic dumping buckets or shovel buckets, and 5 gross tons of ore with the grab bucket.

ENGINES.

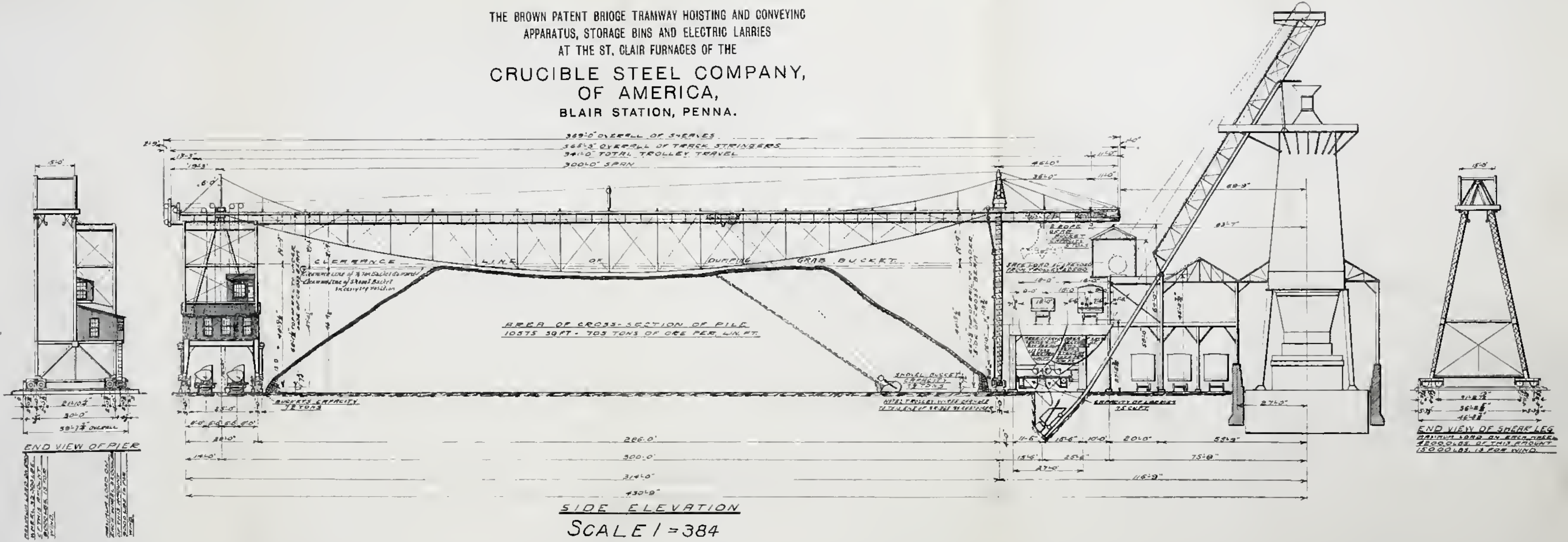
Each of the said bridge tramways to be supplied with 2 special electric motors, together with hoisting and racking drums operated and controlled


TRAMWAY
BINS AND
FURNACES
STEEL
TROLLEY
SECTION
OF ORE
15'-0"
31'-2 13/16"
36'-2 5/8"
46'-8 7/8"
5'-3 1/8"
286'-0"
300'-0"
314'-0"
430'-9"
END VIEW OF SHEAR LEG
MAXIMUM LOAD ON EACH WHEEL
42000 LBS. OF THIS AMOUNT
15000 LBS. IS FOR WIND.

THE BROWN PATENT BRIDGE TRAMWAY HOISTING AND CONVEYING APPARATUS, STORAGE BINS AND ELECTRIC LARRIES AT THE ST. CLAIR FURNACES OF THE

CRUCIBLE STEEL COMPANY, OF AMERICA,

BLAIR STATION, PENNA.



SIDE ELEVATION

SCALE 1 = 384

PLAN
SCALE 1"=1200 FT.

by Brown's patent band friction clutches and brakes. Each of the said drums to be of sufficient face to hold the respective hoisting and pulling lines in the groves without overwinding; the engine to be furnished with suitable levers and foot brakes, whereby the operator can control the motions of hoisting, lowering, bridge travel and trolley travel.

SPEEDS.

The electric hoisting engines will be capable of hoisting the full load in either the automatic dump bucket, shovel bucket or grab bucket at the rate of 350 feet per minute; to travel the same along the bridge at the rate of 1000 feet per minute, and to travel the whole bridge with full load at the rate of 75 feet per minute.

SHOVEL BUCKETS.

Each bridge to be equipped with 1 of Brown's patent shovel buckets, of 7½ tons capacity each.

GRAB BUCKETS.

Each bridge to be equipped with 1 of Brown's patent 2-rope grab buckets, of 5 tons capacity each.

PARABOLIC BINS.

Six hundred and thirty-three feet nine inches of steel parabolic bins, supported on steel piers or columns, and of the same general design and dimensions as shown.

There will also be provided railroad tracks on top of the bins, 18 feet center to center, and suspended trolley tracks underneath the bins.

SUSPENDED TROLLEY TRACKS AND OVERHEAD RAILROAD TRACKS.

Seventy-eight feet one inch of suspended tracks and overhead railroad tracks connecting bins hereinbefore referred to, in front of each furnace, and spaced as shown.

ORE-BIN CHUTES AND GATES.

Ninety ore-bin chutes and gates attached to and made a part of the bins above referred to, to be operated by electricity, steam or air, as may be preferred and decided later on by the St. Clair Furnace Company.

In case electricity is used, there will be furnished the necessary motors, line shafting, etc., to operate the gates. If steam is used, each gate will be provided with its own cylinder levers, etc., necessary to operate the same, and likewise there will be provided piping immediately underneath the bins, but not extending beyond the line of the same. Also in this case the necessary steam power will not be provided. Should it be decided to use air, neither the air compressor, receiver nor piping beyond the line of bins will be furnished.

COKE-BIN CHUTES AND GATES.

Forty-five chutes and gates to be operated by hand and attached to the parobolic bin to be used for the coke supply.

ELECTRIC CHARGING LARRIES.

Six electrically operated steel charging larries, of Brown's special design, of 75 cubic feet capacity each, arranged to run on I-beam tracks, underneath the bins. Each larry to be equipped with one 4-lever scale of 10,000 pounds capacity each.

COKE LARRIES.

Three specially designed coke larries of 120 cubic feet capacity; each to be made so that it can be coupled up and used in connection with the ore-charging larry on the suspended track beneath the coke bin.

ORE AND COKE CHUTES.

Three chutes for conducting ore, coke and limestone from the charging larries into the skip-cars, to be made of steel.

PAINTING.

All structural work to be properly painted at the works with 1 coat of linseed oil, and, after erection, with another coat of linseed oil and iron-ore paint. All inaccessible parts to be painted with 2 coats of iron-ore paint before assembling. All bright parts of the mechanism to be properly slushed before leaving the works.

QUALITY.

The said plant to be in quality of material used, capacity to perform the work for which it is intended, workmanship and in all other respect equal to any of the like plants heretofore constructed and erected by the Brown Hoisting Machinery Company.

MECHANICAL FLIGHT.

By J. Emery Harriman, Jr., C. E.

[Read before the Boston Society of Civil Engineers, May 4, 1904.*]

I shall confine my address mostly to flying machines heavier than the air displaced by them, and shall have but little to say about propelled balloons, except at intervals showing some of the most noted experiments, as they are in an entirely different class.

I shall begin by reading a short description of flight written by J. Bell Pettigrew, published in book form in 1874. He writes:

"However paradoxical it may seem, a certain amount of weight is indispensable to flight. Power and weight may be said to reciprocate by blending their peculiar influence to produce this common result.

"In the aërial machine, as far as yet devised, there is no sympathy between the weight to be elevated and the lifting power, while in natural flight the wings and weight of the flying creature act in concert and reciprocate; the wings elevating the body the one instant, the body by its fall elevating the wings the next.

"Weight, assisted by the elastic ligaments or springs which recover all wings in flexion, is to be regarded as the mechanical expedient resorted to by nature in supplementing the efforts of all flying things.

"Without weight, flights would be of short duration, labored and uncertain, and the almost miraculous journeys at present performed by the denizens of the air, impossible.

"Flight may be divided into 2 principal varieties, which represent 2 great sects or schools.

"1st. The balloonist or those who advocate the employment of a machine specifically lighter than air.

"2d. Those who believe that weight is necessary to flight. The second school may be subdivided into—

"A. Those who advocate the employment of rigid inclined planes driven forward in a straight line by revolving planes (aërial screws); and

B. Such as trust for elevation to the vertical flapping of wings.

"To construct a wing which shall elude the air during the up stroke it is necessary to make it valvular, so arranged that the air, when the wing is made to vibrate, opens or separates the valves at

* Manuscript received July 18, 1904.—Secretary, Ass'n of Eng. Socs.

the beginning of the up stroke, and closes or brings them together at the beginning of the down stroke. Repeated experiment has convinced me that the artificial wing must be thoroughly under control both during the down and up strokes.

"The artificial wave wing can be driven at any speed. It alternately seizes and evades the air so as to extract the maximum of support with the minimum of slip and the minimum of force.

"It supplies a degree of buoying and propelling power which is truly remarkable. It can act upon still air, or it can create and utilize its own currents. The fact that the wing of the insect, bat or bird can be readily imitated and reproduced should inspire the pioneer in aërial navigation with confidence.

"In attempting to produce a flying machine it is not necessarily attempting an impossible thing. Of the many mechanical problems before the world at present, perhaps there is none greater than that of aërial navigation."

In 1889 Otto Lilienthal, a German engineer, mathematician, ingenious inventor and skillful experimenter, published a book on mechanical flight, and made hundreds of experiments with gliding machines of his own design and make.

He made a number of aëroplane machines, and used gravity for the motive power, starting from high hills and soaring to the plains below. He said that the construction of a flying machine for practical operation in nowise depends upon the discovery of light and powerful motors, as, with an ordinary wind, man's strength is sufficient to work efficiently an appropriate flying apparatus.

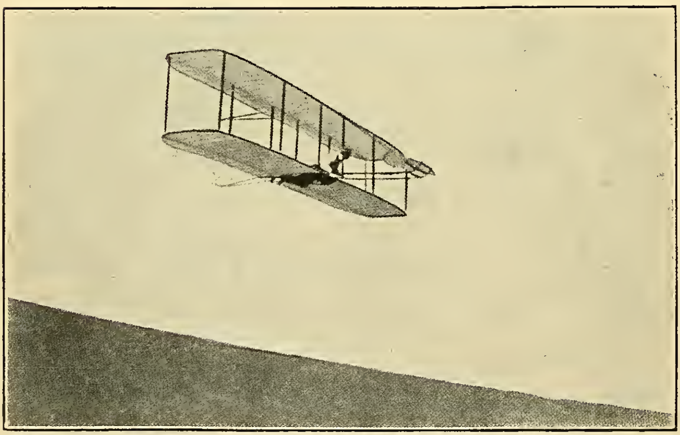
In order to operate such an apparatus with the greatest possible economy, it should be based, both in shape and in proportion, upon the wings of large high-flying birds. The framing and spars should be in the front edge of the wings, as far forward as possible, and the wing tips should encounter as little resistance as possible on the up stroke. No amount of motive power will avail unless the machine can rise, sail and come down again without danger of losing its equipoise.

Experiments should be carried on preferably with full-sized machines carrying a man, and arched wings should be used in preference to plane ones. Lilienthal "demonstrated the feasibility of actual practice in the air, without which success is impossible, and in so doing made the greatest contribution to the solution of the flying problem that had ever been made by any one man."

Following Lilienthal's experiments, Mr. Pilcher, an English

Herr Lilienthal's Flying Machine.

The Soaring Machine of Octave Chanute.



The Wright Brothers' Gliding Machine.

engineer, slightly improved the apparatus and made many hundred glides.

Mr. Octave Chanute, of Chicago, past President of the American Society of Civil Engineers, has contributed greatly to the problem of mechanical flight, not only by encouraging writings and lectures, but by building gliding machines and making interesting experiments with the assistance of Mr. A. M. Herring, a civil and mechanical engineer. In his latest article on aërial navigation, published in the *Popular Science Monthly* of March, 1904, Mr. Chanute writes:

"After 4000 or 5000 years with a problem that has impassioned man, a successful flying machine seems to have been produced by the Messrs. Wright."

In 1897, in his address to the Western Society of Engineers, he said that, "As an engineer, approaching the end of his professional career, it seemed an opportune time to devote some of his leisure to the investigation of the laws which must be hereafter observed by other engineers in compassing the navigation of the air." He said he had hitherto abstained from addressing his fellow-engineers on the subject as some might deem it premature; but he had become convinced, not only by investigation, but through practical experiment, that it was not only possible but almost certain that man will eventually be enabled to make his way through and on the air by dynamic means.

Mr. Chanute took up—

1st. The supporting power and resistance of air.

This first problem is the foundation of the whole subject, and, singularly enough, it is only within the last 6 years that it has been settled beyond question what is the true measure of those properties of air when meeting a surface at an oblique angle of incidence.

2d. The motor: its character and its energy.

This second problem, now nearly solved, was, until 5 years ago, thought to be still more difficult than the obtaining of supporting power from the air. Great advances have been made with petroleum motors, which possess the great merit of dispensing with a boiler, so that, for the first time, the realization of a sufficiently light motor for a dynamic flying machine seems to be within sight.

3d. The instrument for obtaining propulsion.

Mr. Maxim and Professor Langley have made experiments to determine the best form, speed and pitch of the screw to obtain thrust from the air, and have materially improved that instrument which, to reason from analogy in land and water transportation,

seems likely to prove the best device; but both Mr. Hargrave and Mr. Lilienthal have obtained very favorable results with the flapping pinion, which requires no intervening machinery to change the reciprocating action of a piston into a rotary motion, and it seems perhaps possible that success in artificial flight may be obtained by either or both devices.

4th. The form and kind of the apparatus.

(1) Wings to sustain and propel. (2) Rotating screws to lift and propel. (3) Aëroplanes or aërocurves, to consist of fixed surfaces driven by some kind of propelling instrument.

5th. The extent of the sustaining surfaces.

The extent of the sustaining surfaces required to support the weight of a man has in the past caused active controversy and gathering of data. In point of fact, the amount required depends upon the speed of the creature's flight.

6th. The material and texture of the apparatus.

For a beginning, wood will do very well. It is a fact realized by few engineers that the best woods, so long as they remain undecayed, are actually stronger in proportion to their weight than the ordinary grades of steel. Wood is easily and cheaply procured and shaped, and whatever success has hitherto been had in gliding flight has been accomplished with wooden frames covered with textile fabrics.

7th. The maintenance of the equilibrium.

The first requisite for this is that the center of gravity shall constantly be in a vertical line with the center of pressure, and unfortunately the latter is almost constantly varying with the relative wind, with the speed and with the angle of incidence. Until automatic equilibrium is secured and safety is thereby insured under all circumstances, it will be exceedingly dangerous to apply a motor and a propeller.

8th. The guidance in any desired direction.

It has been generally supposed that this would be best effected by horizontal and vertical rudders, but the experiments of Lilienthal and others have shown that slight changes in the position of the center of gravity are more immediate and effective.

9th. Starting up under all conditions.

The solution of the question as to the best methods of starting away from the ground is likely to be one of the last to be practically worked out.

10th. Alighting safely anywhere.

This is the problem which always produces a smile upon its bare enunciation, probably in remembrance of that little experiment

of Darius Green. It may be said to be yet unsolved for the dynamic machine of the future, and yet both Lilienthal's experiments and others showed this problem to be very easy of solution with a gliding machine by simply making use of increased air resistance at greater angles of incidence to stop the headway before alighting on the ground.

Mr. Chanute has carefully prepared his reports of all experiments and illustrated them with more than 30 photographic half-tone pictures.

Mr. Hiram Maxim, the inventor of the Maxim gun, an American in England, Professor Langley of the Smithsonian Institution, Mr. Hargrave in New South Wales and Mr. Lilienthal in Germany in 1888, all at about the same time took up this study of mechanical flight.

Mr. Maxim experimented at a cost of more than $100,000, and constructed an enormous aëroplane weighing more than 8000 pounds with the men, water and fuel on board. It was driven ahead by 2 large screw propellers, 17 feet 10 inches in diameter and 5 feet wide at the tip of the blade. The whole machine rested on wheels on a track of 8-foot gauge, with an upper track to hold the machine down while making experiments under speed. The framework was of strong, thin steel tubes, stayed with steel wires, and the horizontal shape of the surface plane was almost an octagon, covered with varnished balloon material, with a smaller, narrow superposed plane. The angle of the aëroplane was 1 in 8, as Mr. Maxim wished to get as great a lifting power as possible on the comparatively short track with relatively low speed. When the steam pressure reached 363 pounds per square inch and the machine was driven forward, it rose from the lower track and passed upward to the guard track and even tore up about 100 feet of the guard rails before the machine was stopped. Mr. Maxim writes that when, on the first occasion, his aërial apparatus lifted itself clear of the tracks by the energy of its own engines, he felt that the ultimate success of the flying machine was assured.

Professor Langley was the first one to successfully demonstrate, on May 16, 1896, in actual flight, without an operator, a mechanical model flying machine. After years of careful study and experiment he has tabulated most important information that will be of value to all who follow in his line. He made the remarkable and, to the engineer, paradoxical statement that, in such aërial navigation as was there shown to be possible under certain definite conditions, the power required would in theory diminish indefinitely as the speed increased, and that it would actually diminish in prac-

tice up to a certain limit. His experiments have been made in such a thorough, scientific and theoretical way, with every minute detail worked out for every separate part, that it has cost a large sum of money for preparation before a full-sized machine was even constructed; but this expenditure by the Government should not be begrudged, for he has published and fully illustrated all his experiments, which are invaluable to those who will follow in his line.

Closely following Professor Langley's latest experiments, is the remarkably successful demonstration, by Messrs. Wilber and Orville Wright, engineers, of Dayton, Ohio, with their aëroplane. For more than 4 years they have been experimenting with a gliding machine in the same manner as Mr. Chanute and Mr. Herring, and have devoted the most of that time to learning the art of balancing and guiding the machine in soaring flight. They made a number of original departures from the methods of other experimenters, in the first place by assuming a horizontal position, really lying face downward on the lower plane of the machine, and next by transferring the guiding rudder from the back to the front of the machine. To give a clear description of the Wright brothers' machine, and to explain the experiments made by them, would require the reading to you of the able reports made by Mr. Wilber Wright before the Western Society of Engineers, where he was presented by the President, Mr. Octave Chanute, on September 18, 1901, and again on June 24, 1903. These reports are well illustrated by photographic views, and are valuable text-books in the art of flying.

I will read an extract from Mr. Wilber Wright's report, published in the *Independent,* February 4th, this year, which describes their most recent and very successful attempt at flying.

"While carrying on these experiments our power machine was under construction. In dimensions it measures a little over 40 feet from tip to tip of the wings, of which there are a pair. Its length, fore and aft, to use a nautical phrase, is about 20 feet; and the weight, including that of the operator, as well as the engine and other machinery, is slightly over 700 pounds. We designed the machine to be driven by a pair of aërial screw propellers placed just behind the main wings. One of the propellers was set to revolve vertically and intended to give a forward motion, while the other, underneath the machine and revolving horizontally, was to assist in sustaining it in the air. We decided to use a gasoline motor for power, and constructed one of the 4-cycle type, which, revolving at a speed of 1200 revolutions a minute, would develop 16 brake horse power. It was provided with cylinders of 4-inch diameter, having a 4-inch

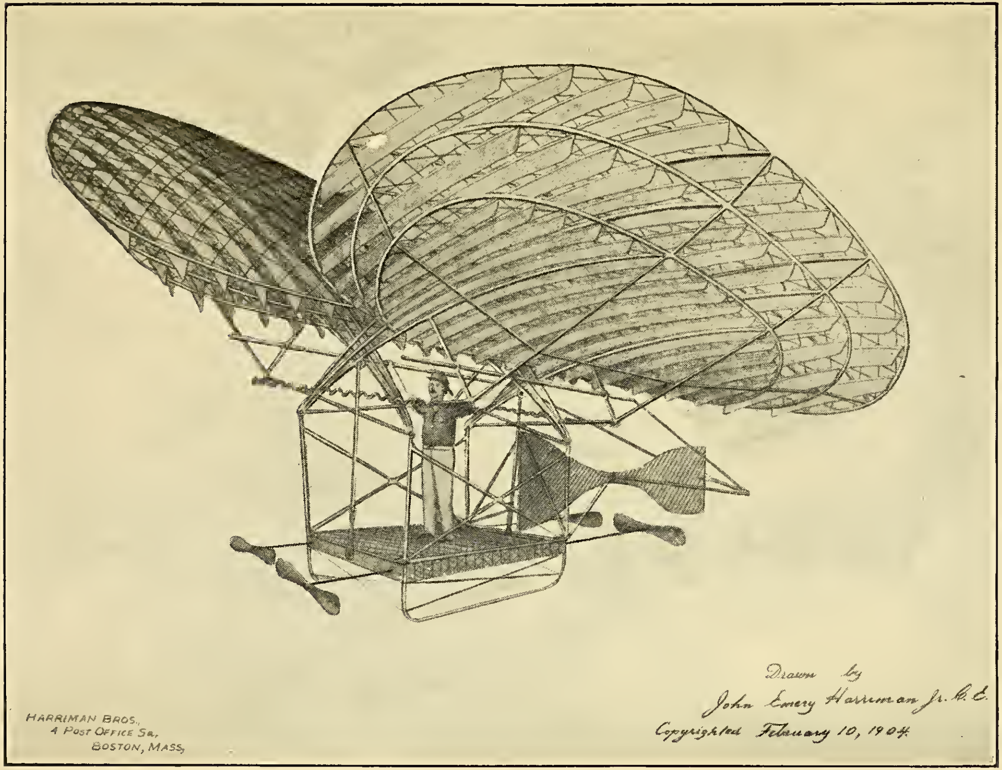
stroke and intended to consume between 9 and 10 pounds of gasoline an hour. The weight of the engine, including the wheel, is 152 pounds.

"We had calculated that the amount of mechanical power provided would be sufficient to maintain the machine in the air, as well as to propel it, the calculation being the result of gliding experiments which showed that when the wind was blowing at 18 miles an hour, the power consumed in operation was equal to $1\frac{1}{2}$ horse power, while with a wind of 25 miles an hour it represented 2 horse power, being capable of sustaining a weight of 160 pounds per horse power at the 18-mile rate. After the motor device was completed, 2 flights were made by my brother and 2 by myself on December 17th last. The apparatus had been placed on a single-rail track, built on the level, the track supporting it at a height of 8 inches from the ground. It was moved along the rail by the motor, and, after running about 40 feet, ascended into the air. The first flight covered but a short distance. Upon each successive attempt, however, the distance was increased, until at the last trial the machine flew a distance of a little over a half mile through the air by actual measurement. We decided that the flight ended here, because the operator touched a slight hummock of sand by turning the rudder too far in attempting to go nearer the surface. The experiment, however, showed that the machine possessed sufficient power to remain suspended longer if desired. According to the time taken of each flight, a speed varying from 30 to 35 miles an hour was attained in the air. We should have postponed these trials until the coming season, but for the fact that we wished to satisfy ourselves whether the machine had sufficient power to fly, sufficient strength to withstand the shock of landing and sufficient capacity to control. Winter had already set in when the last trials were made, but these facts were definitely established, and we know that the age of the flying machine has come at last."

It so happens that the machines and experiments that I have thus far mentioned were all made by civil or mechanical engineers of thorough technical and practical training, and in each and every instance they made a study of the problem before making experiments, which so well demonstrated their belief in mechanical flight that without hesitancy they have publicly proclaimed and published their conclusions without fears as to the final results.

Perhaps, before going further in describing what is being done in preparation for the aëronautic competition at St. Louis this summer, it would be fair for me to tell how I have become interested in the subject. In the first place, I have had the opportunity while

engaged in engineering to watch and study the flight of the American vulture, pelican, flamingo and sea fowl on the coast of Texas, hundreds of half-tamed sea gulls at the docks of Seattle, the broad-winged hawks near Lake Champlain and the large fishhawks among the islands of Penobscot Bay, Me., and in all instances I have been greatly impressed with the ease and grace of the slow flapping of the wings and the ability to soar through space. I have noticed particularly that at the same time with the downward flap of the wings there seemed to be a voluntary rise of the body of the bird, and as the wings were raised again the body seemed to drop slightly. It was this movement that inspired me to try to design a machine wherein the weight and muscles of the operator should assist in opening the wings on the upward stroke, and the release of that weight and power, by his jumping slightly and transferring it to the wings, should assist in the downward stroke, and my study resulted in the design here shown in perspective. This movement alone, to my mind, would reduce to a minimum the extra mechanical power necessary to flap the wings; and it is one of the principal points of my *design* here open to your inspection. It was shortly after this, while studying what had been done by others, that I found, in the library, what to me seems one of the best descriptions of flight published, namely, "Animal Locomotion and Aëronautics," by J. Bell Pettigrew, F.R.S.E., which I have already mentioned as being published in 1874; and it was the last sentence I have already repeated that gave me the assurance to hold to my belief, namely, "In the aërial machine, as far as yet devised, there is no sympathy between the weight to be elevated and the lifting power, while in natural flight the wings and weight of the flying creature act in concert and reciprocate; the wings elevating the body the one instant, the body by its fall elevating the wings the next." The downward flap of the wings would be assisted by springs underneath, of a tension about equal to the balanced weight of the body of the machine and operator. Next, in the design of the wings I would form double trusses, to pivot and cross each other, with the car suspended from the overlapping interior ends, which would have a tendency to raise the outer ends of the wings. The edges or circumference of the wings would be connected with the trusses and all would be held together by cross-cord bracing. From this network bracing I would suspend a series of parallel flaps that would close as the wings moved downward and open as the wings moved upward. I would use 2 or 3 wings on each side, one above the other, with a spread, when open, of about 36 feet from tip to tip. The length, from front to back of wing, would be about 18 feet, but



HARRIMAN'S AËROMOBILE.

it would not be entirely covered with the hanging flaps, as I would leave a space between the front and back part to increase the stability and safety of construction. To my mind, it would steady the machine.

I would follow the design of Wright and Chanute in making the wings convex on the upper side and concave below, with a curve in height equal to about one-ninth of the distance from the front edge. I would first try a gasoline engine of about 6 horse power to raise and lower these wings, and would use another engine of about 6 horse power to revolve propellers in front and back of the machine for pulling and pushing it ahead. I cannot believe otherwise than that a valvular wave wing will prove much more efficient than a horizontal revolving propeller in raising the machine, but I should not count on the flapping of the wings to assist very much in the forward motion, but would apply vertical propellers as already described. I would also attach an overhead center wing or canopy to act as a parachute in holding the body of the machine up while the wings are ascending. By this design the weight of operator, car and motive power would be in about the center of the machine and quite a little below the center of gravity, making the machine act as a parachute in case of accident to the propelling mechanism. The weight of this entire machine should not exceed 600 pounds, including the operator, and the cost should not exceed that of an automobile, say $2500.

I believe in flexible wings rather than the rigid aëroplane, as it can better adapt its surfaces to the variable wind pressures. After good headway was once gained there would be no need of further flapping, as the vertical propellers would force the machine through and on the air the same as a rigid machine. The Chanute, Wright and Lilienthal machines slowly glided downward through the air without motive power on a grade of about 15 per cent. It is therefore shown that in every 100 feet traveled, at even a slow rate, it is only necessary to gain 15 feet in order to maintain a horizontal line of travel, while under speed the drop per 100 to be overcome is a mere trifle, and in fact, by the proper inclination of the machine, a rise may be made. The rise and fall of the machine are directed by the operator's changing his position forward or backward, and the turn in direction is made by his shifting his weight to the right or left.

It seems to me that the problem of the mechanical flying machine has already been sufficiently solved and demonstrated to warrant immediate attention to it as a legitimate proposition for progressive business men. There is no more alluring and universally

attractive commercial enterprise before the public to-day for promotion, and when people are brought to realize and believe that this wonderful feat has truly been successfully done here in our own country first, by two conservative Americans, the Wright brothers, of Dayton, Ohio, they will wonder why this problem had not been properly attempted before; realize, from what has already been demonstrated at a cost of less than $2500 for 1 machine, and from what will be seen again by the public in a few short months at St. Louis, that the very first attempt at operating an aërocurve or aëroplane flying machine with modern mechanical motive power attached, bearing an operator, succeeded! Not such a wonderful feat after all when viewed from a mechanical standpoint; no unseen parts or movements, no intricate mechanism, no delusion, but reality.

As soon as the public is relieved of its skepticism and the individual investor is given an opportunity to see and know that mechanical flight is not an idle dream or cranky notion, then those who blindly undertake its imitation, regardless of future investigation or knowledge, will possibly make better or worse attempts at reproduction than the true investigators have made in development. It is a problem also open to those who can afford, and who believe in, scientific research and process, regardless of the pecuniary return that may be derived from the successful use and manufacture of the machine. When such men as Prof. Elihu Thomson, Alexander Graham Bell, Emile Berliner, Hiram Maxim, Langley, Chanute and other well-known scientific men give this problem their serious study and attention, with the indorsement of practical men like Mr. Munn, of the *Scientific American;* Colonel Church, of the *Army and Naval Journal;* Mr. Merrill, of the New York *World;* Mr. Brisbane, of the New York *American;* Mr. Walker, of the *Cosmopolitan;* Charles Francis Adams and other well-known Americans, does it not seem somewhat unwise for the non-investigator and non-believer to criticise these endeavors?

One of the greatest events and attractions that the world ever knew will be the aëronautic competition at the St. Louis Fair, open from the first day of June to the first day of October, over an L-shaped track some 30 miles in circuit, for a capital prize of $100,000 and $50,000 in minor prizes. The course will simply be marked out by 3 captive balloons.

Unlike the railroad, the thoroughfare, the open plain, the river, the lake or the ocean channel, the airship or aeromobile will not be confined to grades and alignment. For the flying machine there will never be expensive rights of way to build, protect and maintain, no regular confined channel to follow, buoy, light and map. The direc-

tion and elevation above surface are free from obstruction, no matter which way one may travel above sea or land. The air is the only universal highway that leads anywhere and everywhere. It connects all nations, seas and lands alike, without break or obstruction, day or night, and the elemental changes will not be many or so difficult to overcome as those on land or water.

The cost of evolution and construction of the flying machine will never be as great as that of the steamboat, steam engine or electric car or the more recent automobile, and in the near future the flying machine should be a familiar sight.

FERROINCLAVE AND CORNELL'S PATENT DOVE-TAILED LATH.

By H. C. Harrower, Member of the Engineers' Society of Western New York.

[Read before the Society, May 3, 1904.*]

I was much interested in Mr. Cobb's article under the title of "Ferroinclave," published in the Journal of the Association of Engineering Societies, for January, 1904. It struck me as another case of history repeating itself, as the lath there used seems to be a reincarnation of Cornell's patent dovetailed lath.

When I entered the shops of J. B. & J. M. Cornell, in New York, in 1872, they were the largest workers in structural and ornamental iron work in the country, and, among other things, they did a very considerable business in this lath. It was manufactured under their own letters patent, and had been for 15 years or more.

This lath was made from sheets of No. 24 or No. 26 sheet iron, which were passed through a special corrugating machine, which produced a finished sheet of lath 8 feet long and 2 feet wide, about $\frac{1}{2}$ inch thick from out to out of corrugation. These corrugations were $\frac{5}{8}$ inch across and the sides were recessed back, forming a dovetailed section. The result was a lath with a perfect clinch. It was used very largely by the Messrs. Cornell for partitions in fireproof buildings.

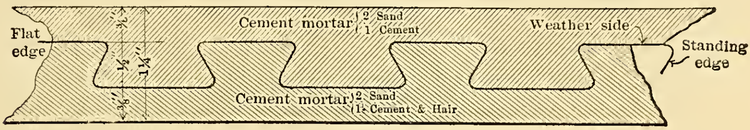
In partition work, the studs were made of 4 x $\frac{3}{8}$-inch iron, plugged on both edges. These were set up with the necessary door openings framed in. Then the sheets of lath were placed against the studs, the holes punched through for the plugs and the plugs riveted down. In a similar way the lath was used in ceilings.

Of course a man of Mr. Cornell's mechanical ability would see many other uses for the material, and among the rest he used it on a skeleton frame for mansard and deck roofs. After the Boston fire the firm did a large business in the rebuilding, and I recall two buildings, where it was used in the roof. These were the Transcript Building and a building for the Sears estate, on Summer Street, near Washington Street. Both of these buildings had mansard and deck roofs. Both were framed up with light beams and the whole covered with the dovetailed lath. The mansards were then slated and the decks covered with a coating of Neuchatel asphalt, about 2 inches thick, and the mansards were plastered on the inside.

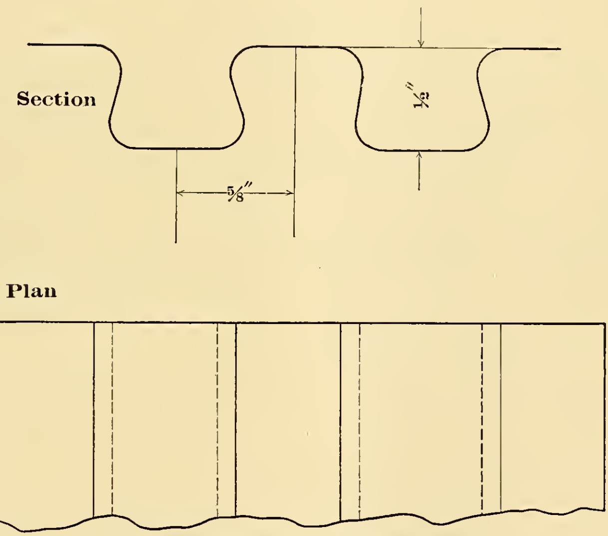
* Manuscript received June 2, 1904.—Secretary, Ass'n of Eng. Socs.

Both of these buildings were finished before I went to Boston. in 1874, to take charge of the branch office, but I have good cause to remember them, for I had a great deal of trouble keeping them tight, leaks being caused by the cracking of the asphalt due to the expansion of the iron.

My principal work in Boston was in the construction of the Milk Street building of the Mutual Life Insurance Co., of New York. This building was very expensively finished, being strictly



Section of Complete Ferroinclave Roofing



Cornell's Patent Dove-tailed Lath

fireproof, and all the interior finish being of marble or iron. All the partitions were made as above described. After the building was enclosed, it was found that the 200-foot tower was settling badly, and it was determined to lighten up the floor filling around the tower as much as possible. The old style brick arches had been put in, except in the tower itself; and drain tile of varying diameters was used to fill in the haunches, where the arches were in place.

In the tower itself we put in an extra set of light beams.

blocked up from the regular floor beams, and on these we laid the corrugated lath with a light filling of cement under the finished floor. Shortly after this time, cheaper forms of lath came into use, such as the Bostwick and stiffened wire, and when I left the Cornells, in 1884, the use of their lath had largely diminished, and I am unable to say whether it is still made.

For a number of years after coming to Buffalo, I had a sample of the lath in my office, but it has disappeared and I have had the small sketch, shown herewith, made from memory.* You will notice that it seems to be identical with Mr. Cobb's material, and that, in the Transcript and Sears estate buildings, we used the lath in the same way that Mr. Cobb used his material.

I trust that you will bear with me in these somewhat crude remarks, as Mr. Cobb's article was like a call from an old friend.

DISCUSSION.

Mr. H. F. Cobb.—United States Patent No. 117,384, dated July 25, 1871, and granted J. B. Cornell for fire-proof roofing, covers a roof construction composed of corrugated iron with a section like the standard corrugated iron, or having a section somewhat like ferroïnclave. To this a slate, or imitation slate, is attached with screws or copper nails. This slate rests directly upon the corrugated iron upon the upper side. Upon the under side the corrugated iron is left uncovered, or, if it is shaped somewhat like ferroinclave, it may be plastered.

Mr. Cornell's claims are as follows:

A fire-proof roof formed of slate C, and corrugated metal sheet A, applied to a building in the manner specified.

Second. The slate C, sheet A, and plastering E, combine and apply all and for the purpose specified.

The writer cannot see that there is any similarity between Mr. Cornell's old invention and Mr. Brown's invention of ferroinclave, except in the fact that one of the sections of corrugated iron advocated by Mr. Cornell has a dovetail shape and is used to hold plaster on the under side. Ferroinclave roofing is a reinforced concrete construction, while Mr. Cornell's is not. In the Cornell construction the corrugated iron will soon rust entirely away and permit the whole roof to fall. Ferroinclave is entirely protected by

* For comparison, Fig. 1, of Mr. Cobb's paper, from the Journal for January, 1904, showing section of the ferroinclave lath, is reproduced herewith, by courtesy of the Brown Hoisting Machinery Company.—Secretary, Ass'n Eng. Socs.

Portland mortar and will last indefinitely. Mr. Cornell must make butt joints between the ends of his sheets, where ferroinclave sheets, with tapered corrugations, will fit into one another at the ends and so make the surface continuous.

Mr. H. C. Harrower.—I am not familiar with the details of the J. B. Cornell patent, but I do know that the material manufactured under it was not standard corrugated iron, but was in fact identical in shape with the material that Mr. Cobb shows in his drawings illustrating ferroinclave. It is also a fact, that while in mansard work it was used as Mr. Cobb states, on deck roofs it was used in practically the same way as that in which Mr. Cobb uses his ferroinclave. One of these roofs, that on the Transcript Building in Boston, came under my personal supervision, as stated in my paper. Here the material was completely imbedded, having two inches of asphalt on top and one inch of plaster on the under side.

Mr. Cobb may be right as to the claims of the original patent, but Mr. Cornell evidently found other practical uses for the material, and among them was that claimed by Mr. Cobb as originating with ferroinclave. Mr. Cobb is in error in his assertion, that Mr. Cornell made butt joints. On the contrary, they were lap joints, one end of each sheet having the corrugations opened enough to allow the next sheet to slip in about two inches. After the sheets were corrugated, they were placed on a special table, and a mandrel, shaped to fit the corrugations, was forced into one end, enlarging it for the purpose named above.

ON CONTEMPORARY TECHNICAL EDUCATION.

ADDRESS OF JOHN R. FREEMAN*

ON BEHALF OF THE ENGINEERING SOCIETIES AT THE

INAUGURATION OF PRESIDENT CHARLES S. HOWE. CASE SCHOOL OF APPLIED SCIENCE, Cleveland, Ohio, May 11, 1904.

Mr. President:

As delegate on behalf of our Engineering Societies, I must explain that these also are Schools of Applied Science. They are the more attractive to students since they hold no examinations; all studies are elective and voluntary; one recites only when he feels like it; and the social element is pre-eminent.

Into this university of the Engineering Societies, we hope to receive all of your graduates and to retain them as fellow-students and warm friends to the end of their lives.

APPRECIATION OF THE TECHNICAL SCHOOL.

In speaking on behalf of the engineering profession, my first words must acknowledge our great debt to the technical school and that this debt is increasing from year to year. Our members are coming to be recruited in an ever-increasing proportion from the technical graduates ([1]).†

From the researches conducted in your laboratories, we obtain much of our most valuable engineering data.

Our best books of reference for the practicing engineer are nearly all prepared by the professors in these technical schools ([2]).

The strongest foundation for a country's future industrial and commercial welfare is to be found in Schools of Applied Science, well equipped, guided by men of broad mental horizon. This is scantily appreciated as yet by the mass of strenuous Americans, but it has long been clearly seen by the Germans, and is beginning to be seen by the English ([3]).

The cost of duplicating the land, buildings, equipment and endowment of the largest and most complete technical school in the United States is little more than half the cost of one of the latest battleships, and the running expenses of the largest technical school per year are less than those of a battleship ([4]), The Technical School has a use no less important than the battleship in the "first line of

* Vice-President American Society of Mechanical Engineers; Member Board of Managers, Association of Engineering Societies.

In compliance with the invitation received, and, at the request of the Chairman, Mr. Freeman represented the Board at the inauguration of President Howe.

† Footnotes. See end of paper.

national defense." The time has already come when the commonwealth and the nation should contribute more liberally to the burden of its support and help it to ever broader usefulness. With the increasing numbers of students and with the rapidly increasing cost of laboratory facilities needed for the best training, the need of funds is greater than private munificence can be relied upon to meet. The demonstration of their great value to the prosperity of the state is already complete ([5]).

In the re-awakening of the old spirit of commercial adventure in foreign lands, we must to-day base our hope of success on superior excellence and economy of manufacture and in the calling of our engineers to foreign lands.

The growth of our cities is laying a burden of new and larger problems on our departments of public works, a burden which only those trained in the Schools of Applied Science can carry wisely and well.

The business man, when he comes to see these matters clearly, will urge again and again a generous support to Schools of Applied Science by city, state and nation when private munificence falls short.

These schools need, as managers, the strongest men that can be found, the men of broadest horizon, the men that can arouse the noble ambitions of young men toward advancing the state of an art and that can impart the spirit of joy in work.

APPRECIATION OF THE TECHNICAL GRADUATE.

For twenty-five years I have been observing the increasing respect paid by our industrial leaders to the training gained in the technical school. The technical graduate himself has come to better understand his own limitations, and his need of a course outside, under instruction from the foreman and the mechanic. The man of business is coming to understand that there are "first," "seconds" the "thirds" produced, that some excel in judgment and some in skill, and that it is not the mere fact of being a technical graduate that brings success, but that, given inborn executive ability, the training of college or technical school gives to its graduate a tremendous advantage over the man of equal native force who has not this training.

Twenty-eight years ago the finding of openings by my own fellow graduates was difficult and slow,—not a third of our men found openings of fair promise within the first six months; the average "captain of industry" did not then know just what a technical graduate was, or what he was good for.

We then listened to prophesies that the annual output of engineering graduates would soon overstock the market. To-day, notwithstanding that, during the past quarter of a century, technical schools have multiplied on every side and that classes in many of the older ones have increased fourfold, the output is quickly absorbed. The department head in one of our largest technical schools has told me repeatedly that in each recent year he has applications from managers of important works for double the number of his graduates, and it is said that certain large and progressive concerns send an agent around the schools in January to select from the brightest of those who are to graduate in June.

The mere register of the occupation of the graduates from any leading School of Applied Science is a most eloquent commentary on the commanding influence of these schools.

Twenty-five years ago, among managers of works, I heard much about the good *practical* man and his superiority to the theoretical college graduate; to-day it is coming to be generally recognized that the *good* practical man is the one who has graduated from a technical school and who has then been seasoned by a few years of experience in bumping against corners of construction, and the technical graduate of proved business ability is in special demand.

The Technical School, the School of Mechanic Arts, and the Mechanics Correspondence School, each has its special and distinct value in our industrial life. We should make the technical school attractive to the brightest minds, and should look to it for our industrial and commercial leaders and for the best custodians of the public health, of our water supplies and other public works.

In order to get the most out of the existing technical schools, let us keep in mind the limitations within which they can do their most efficient work, and the fact that not every kind of work will be best done by a technical graduate. The students found without promise of final success should in all kindness be allowed to depart and not hold back the best.

Doubtless a man may give lines and grades as well, may drive an engine or detail steel work better, if his four years of early manhood have been spent gaining this dexterity and skill outside the technical school. The late Col. T. J. Borden, a sympathetic thoughtful man of 40 years' experience as manager of large industrial works, and himself a technical graduate, told me that for many years he had been observing that a faithful uneducated laborer would in general keep a more correct tally sheet of the unloading of a cargo than the bright high-school graduate whose thoughts were flying off to other things; that a large factory

engine would be run with better attention and fewer breakdowns by a graduated stoker or oiler than by an expert machinist, who was liable to be scheming out improvements and to have his mind busy with something other than the mere operation of this machine; that often the best routine work was done by a man who was not capable of anything very much better.

The young man who is to follow a narrow routine through life will not have much added to his efficiency, as a machine, by the long elaborate course of the technical school. For those constitutionally deficient in ambition, or for those unfortunates who can never comprehend the art of getting on in the world, these four extra years are ill spent at school, but there are plenty of young men for whom this training of the technical school is the best possible training, and there is plenty of opportunity for a larger number of these men than all of our present schools can graduate.

Men cannot be shaped on the interchangeable system of the American Machine Shop, each will be a "special," and, as already remarked, there will be produced "firsts," "seconds," and "thirds," but fortunately the demand for all types and grades exceeds the possible supply for years to come.

Among the graduates, some will possess that rare faculty for which "initiative" is the phrase of the day, and among these there will be some who will possess that quality of balance and judgment, and attain such knowledge of men, that they will become great leaders, the captains, will establish their own industrial works or be called to the $10,000 positions which are always so hard to fill right. Others, without this business insight, but perhaps more learned and more skilful in engineering, will design machines and bridges, supervise factories, become the lieutenants and fill the $4000 and the $2000 positions, and a still larger number will do noble work as the sergeants, corporals and privates and be made better men by the broadening of their minds.

The training of no school can make the square peg fit easily in the round hole, and, out of a hundred boys, but few are born with the ear of a musician or the eye of an artist, or with the observing, inquiring, ingenious, imaginative mind, which schools can stimulate but cannot create, and without which conspicuous success in constructive engineering is impossible. But for the young man so fitted by nature, a technical school of broad scope and high aim is a royal road.

A ROYAL ROAD.

The old statement that "There is no royal road to learning" is untrue. The man of affairs has come to understand that *the*

technical school is a royal road to learning, a shorter road, an easier road, through a more beautiful landscape, and in equal time attaining a broader outlook.

A man with the earnestness and persistence of John Brashier, the strong purpose of John C. Hoadley, the rugged common sense of Edwin Reynolds, the strong, kindly heart and quick intelligence of John Fritz, or the genius of Edison, may reach an equal height by a longer and more arduous road, and, like the athlete, increase his strength and harden his endurance in the greater effort; but the royal road of the technical school, in its four years, may, from its small group of a hundred, gathered part by chance and part by process of natural selection from more than ten thousand school boys, bring perhaps ten or twenty to the point that otherwise not more than one or two or three could hope to reach in twice these four years.

The technical school is not exclusively for the brilliant man. Much of the world's best work is done by the man of slow-moving intellect, to whom the good Lord has given the greater treasure of persistence, of steadfastness, with enough of imagination to feel what is concealed within the cloud on yonder difficult and distant hill.

There is danger in relying upon lectures and reading for teaching, and upon written examinations for measuring up a student and his fitness to continue on his four years' course. One of the greatest advantages of the technical school is found in its Laboratory method, for the reason that the personal, individual contact with the student daily in the laboratory gives an opportunity for helping the one who is slow to develop himself.

I have had perhaps twenty graduates tell me in familiar talk that the most helpful man to them of all the "Technology" professors was the lamented Holman. Why? First, because he was intellectually great and a noble man, and second, because he took pains to get acquainted with them and their individual needs, *in the laboratory.* The ablest professors should be brought into earliest possible contact with the freshmen in the laboratory.

THE OPPORTUNITY FOR THE TECHNICAL GRADUATE.

For a few moments past we have been considering the broader appreciation, by men of affairs, for the work of the technical school; let us for a moment review the causes of its great opportunity.

That the manufacture of power was the mainspring of the onward movement of the nineteenth century was made plain, perhaps more ludicidly than ever before, by that great engineer, whose re-

cent loss we mourn, George H. Morison, in his Phi Beta Kappa address at Harvard in 1895.

In the skilful application of manufactured power lies the great opportunity of the engineer.

The distribution and use of manufactured power are increasing by leaps and bounds in a way that few of us can see in perspective.

It moves a thousand cotton spindles guided by a single hand, with the power of more than a thousand horses, it ([6]) draws your "20th Century Express," large cotton factories in Montreal are driven by a waterfall nearly a hundred miles away, the power of Niagara rends the strongest chemical affinities. The chariot, as made in Cleveland, is horseless, but it is propelled by the power of 24 horses, all generated in a little space and derived from a harnessed explosion. In another part of your city, the most delicate and accurate engraving that the skill of the world has known, an astronomer's circle with markings correct within less than a second of arc, may go on in solitude as a result of a laborer shovelling coal under a steam boiler. To-day there is far more steam power used in Lowell than water power, and in your city of Cleveland the power manufactured from coal far exceeds that of the greatest single development of water power in the world ([7]), Niagara not excepted. The General Electric Co. had on its books, on Jan. 31, 1904, undelivered orders for steam turbines of an aggregate power of 350,000 horse power, an amount three times as great as the present total generation of power from Niagara and nearly half as great as the total water and steam power combined, in the six New England States, found in the census of 1880.

With the aid of unlimited power, work is performed in a larger way and with greater rush, and with this comes the greater need of executive ability, of captains and corporals of systematic, observing habit, equipped with the tools and training of the technical school.

This is a transition period, and never was there such opportunity for the trained engineer. Mechanical production must supply the natural increase due to the growth in population, and replace machines worn out by service, and even new machines by something newer. Here in Cleveland your horse cars were not worn out when the cable car replaced them, your cable railways were not worn out when the electric car came in. Not only the equipment, but the shop that makes it, must largely go into scrap.

Two or three years ago one of the leading engine builders of the world began on new shops in a city on the Great Lakes, the largest of their kind, designed for building engines of the most massive

type. Hundreds of thousands of dollars were expended on these shops and their heavy machine tools, but, before these shops were occupied, customers were inquiring, not for engines but for steam turbines.

The leading pump builder of America began two years ago on new shops near New York, these also to be the largest in the world; the plans had been matured by years of study, for building pumping engines of the ordinary reciprocating type. Before these shops are ready for occupancy, the old and simple and inefficient type of centrifugal pump is suddenly so improved as to threaten a revolution which may profoundly change the type of shop equipment demanded.

A maker of valves and pipe fittings, a concern which had kept steadily up-to-date for more than a quarter of a century, started, about two years ago, to supply its expanding trade by a factory on the shores of Long Island Sound, designed to employ at first 2000 and later 4000 men. The plans were matured with rare care and judgment. First, their man of greatest skill in shop methods plans for his various machines and lays out his floor space. Next, the skilled mill engineer makes plans to house that floor space in. Next, an architect, of national reputation for his inborn sense of beautiful form and graceful line, models the outlines of exterior wall and windows and roof. Machine tools of latest design had been purchased, apparently everything had been provided for, when, just as the roofs are on, the successful demonstration of a new kind of tool steel, which permits of far deeper and more rapid cuts, calls a halt and requires a radical change.

All this is recent and the end is not in sight. Seventy-five years ago, when Cleveland was a frontier village, within the memory of a few men now living, the dry dock in the Boston Navy Yard was the most monumental piece of engineering construction and the greatest single work of internal improvement yet completed within the United States, and the total of manufactured power in the United States did not equal the output of one of the large power stations of to-day.

It is only forty years since the first distinctive general School of Applied Sciences, or Institute of Technology, in this country, began, after years of patient explanation and pleading by that lovable, eloquent, prophetic, noble man of science, William Barton Rogers, and how profoundly it has influenced the whole course of higher education.

Not long ago I had a letter from a fine old gentleman of Boston who, educated in France, in his day and generation had been the

best educated engineer in America and who began his practice on the earliest steam railroad, under the great Stephenson, one whose pleasure it had been through a life of uncommon length to follow engineering developments in varied lines. This man, who had seen the railroad born, the use of electricity and a thousand other marvelous results of scientific study, wrote of *the greater* opportunity of the young engineer of to-day!

Although the lines of work formerly recognized as engineering may be crowded, there are, on every side, unworked fields in which the trained engineer, possessing business ability, be he builder, sanitarian, chemist, mechanic, or electrician, can introduce system, discover causes, lessen cost and improve the product and find for himself a competency and joy in work.

A PLEA FOR BREADTH OF CULTURE IN THE SCHOOL.

The other speakers to-day are presidents of colleges, educators of wide experience and national reputation, and it savors of rashness for me, in their presence, to venture opinions upon the aims and methods of a technical school, but during my twenty-five years of taking on one or more technical graduates in almost every year, and trying, through them, to keep in touch with the schools, I have so often found what has seemed to me a misapprehension among students, friends and patrons of technical schools, that, to an audience of patrons, teachers and students, a few words, from the standpoint of a business man and practicing engineer, may have some interest.

Why do we not find the greatest prizes of the industrial works and of civic administration going *more* often to the technical graduate? The commercial department pays a better salary than the engineering department. We have all seen plenty of examples to prove that technical training can be of itself an aid rather than a bar to commercial success.

Have our men got too narrow a training in the technical school?

Within the past week I have chanced to hear two heads of concerns, employing many scientific men, say in substance that the old academic education fits better for the position where one deals with men, or for the $10,000 position, while the technical school fits better for the position that deals with materials, or for the $4000 position, and I note that sons of my old classmates are being sent first to Harvard or Yale or Dartmouth for *four* years and then to "Technology" for a *two* years course in science.

Six years time, from 18 to 24, is more than the average young

man can afford to spend at school. It brings him into the works too late. When we more fully appreciate that education, rather than information, is the true aim of the technical school, then a broad education and sufficient information can both be given in a four years' course.

Can we not give a better education to the great majority of our students and plant in them thirst for information, by doing fewer things more profoundly and putting more emphasis on the personal element?

Is not one great captain of science or industry, like Pasteur, Kelvin, Ericsson, Bessemer, Westinghouse, Brush, Mills or Alex. Brown and a hundred others, worth more to his country and his neighborhood than a roomful of the very necessary and useful sergeants and corporals of science and industry?

Cannot our school do the most good and best serve all, and best stimulate the ambition of all, by trying to fit men for the position of captain; and, if the man, skilled in the application of science, has also executive skill and such knowledge of men that he can negotiate, convince and arouse men, will not he have a wider opportunity to do good and to advance the state of the art and the public welfare; and shall we not, by addressing our teaching to the highest grade, thus produce more of the $10,000 men and at the same time better $4000 men?

In separating students into many courses, is there not danger of splitting things too fine? Have the schools not already gone too far in specializing for the undergraduate?

It is a matter of slight importance to the builder of machines or of water works whether he takes the course in mechanical engineering, civil engineering, or general physics, *if he is fortunate in his teacher*.

The chief function of the Technical School is not the filling of a man's memory with formulas and with knowledge of how everything is made, but rather is the training in methods of thoughtful research, of teaching how to put the question and where and how to find the answer, of how to set traps for our own unconscious errors, how to save time by understanding just what degree of precision is necessary to the case in hand, how to measure with certainty the limits of the ever-present error, and above all to develop and strengthen a warm, enthusiastic, undeviating love for the truth.

In my own college days, I did not have it made plain, and I failed to grasp the fact, that perhaps the greatest opportunity of college life is that of coming to better know one's fellow-men, and it is in

failure to appreciate this, more than in any other one feature, that the professional school has failed in comparison with the older colleges. In the protest against the old education, exemplified in the early development of the Massachusetts Institute of Technology and other similar schools, the pendulum swung beyond the center, and the value of the social idea was for a time not appreciated. To many of us there was lost the inspiration and broadening, the deeper understanding of humanity that may come from entering into the daily life of the ancient civilizations enough to understand that human nature is much the same through three thousand years. We missed that focussing and sharpening of the wits which comes from taking time for the discussion of current events with our fellows.

We had a professor who wisely read to his class those verses on The Deacon's Masterpiece, "that was built in such a logical way," as typifying the ideal machine. McAndrews' Hymn may teach a deeper lesson. The man should be led to find inspiration in his machinery, while in the technical school.

A few weeks ago, in Chicago, I sat beside a classmate, a former "grind," now a successful man of business, at a gathering of the graduates of one of our largest technical schools. Said he, "We were brought up wrong in being taught to spend so much time on our studies; we practiced a false economy in being too thrifty in our earlier years." We were too late in learning that opportunity, sustaining power and a stimulus toward success, came more from a wise good-fellowship than from high scholarship, and that the art of being what in your terse Western phrase is called "a good mixer" was an art well worth time, money and paternal advice to cultivate. It is by giving the technical graduate a wise start in this direction that he will ultimately come more often into the larger opportunity and the higher salary of the commercial end.

This social feature is, in the final analysis, the chief value of the engineering societies. Although papers are presented in which one engineer so presents his experience that a hundred others may find each his own course more clear in attacking a similar problem, although one may hear presented in an evening hour the results of experiments and research that have cost a year of toil, all so summed up in a few lines of formulas or constants, that a repetition of this labor and expense is saved to all who follow, and although the master mind may publish in the transactions a study upon difficult and disputed points that will lighten labor or save mistakes to many of his fellows; yet, after all, the pre-eminent usefulness of the Society of Engineers is in the bringing of men into

personal relation, inspiring the young man by personal contact with the man who has done things, giving the older men a chance to size up the growing young men; and, among equals, it removes the bitterness to personally know our successful competitor and to know that he is a good, honest man.

If it be asked what suggestions can be offered to his friend, the teacher, by a practicing engineer, who has for twenty-five years enjoyed taking "green graduates" and trying to help them on their post-graduate course, I venture the following:

Dwell on the principles of research, fill the student mind with a comprehension that the school is not so much for filling his memory with information as for teaching the scientific method.

Give more attention to the principles of writing reports in clear, exact and vigorous English, to measuring the exact meaning into every sentence. Teach what may be called "commercial rhetoric," bringing the result quickly into the view of the busy man and seeking to so arouse his interest in the opening paragraphs that he will continue reading instead of laying it aside for the leisure hours that may never come.

Emphasize the need, in the practical world, of "getting there" on time.

Recognize that a judicious "cramming for examination" is legitimate, and that how to do it with the least internal friction is a most worthy subject of instruction. In closing business contracts and in expert work, it is a much practiced and most useful art.

Direct attention to the conditions necessary for obtaining a maximum output from the human machine. How seldom a man gives, to his own body, the same care he would give to that of a $1000 horse! Long hours under stress in emergency are easy if the man knows how to avoid fatigue through variety, and has the will power to practice what he knows.

Probably there is no better way to save time and cultivate judgment than by practice in quick estimates between limits. What does that stone weigh? Not more than 6 tons, not less than 4. What will that casting cost? Not less than $50, not more than $100. If the owner asks the cost of repairing the tangled smash-up of ten minutes ago, the young engineer can give him almost instantly an estimate that may serve his purpose, and be correct, if he states it between limits, as, "not more than $10,000, and not less than $1000." Twenty-four hours later, he may be able to state it as not more than $5000, and not less than $4000.

Urge upon your colleagues the fact that they owe it, to their fellow-citizens and to the loyal intelligent public that supports the

school, to promptly and continually translate the story of the latest discovery of abstruse science down to the understanding of the well-educated non-technical man.

Stimulate the interest of the students by continually bringing before them the results of the latest research and of what is being found out in other departments of the school.

Recognize the fact that these four years' time, with their attendant expense, are too valuable to be devoted to the attainment of mere manual dexterity. This can be more cheaply learned in the field or workshop than in the school. Do not shrink from turning out graduates who will be strong on theory, while perhaps weak on practice. They can get their practice outside after graduation, and perhaps under the quickening influence of some shortlived ridicule by the routine workman. The sound foundation of mathematics, the facility in handling and transforming difficult equations, the mental grasp of difficult considerations, so as to state them in the language of mathematics and quantity, must be acquired in the Technical School or the chances are they will never be acquired.

Finally, to the many students here, I can bring back no better word, from out the years since I left similar pleasant places, than to remind you how largely the success of a school depends on atmosphere and that every man has a share in forming public opinion; and to urge you to fill the student atmosphere with the fraternal spirit and with ideality,—ideality, with the love of thoroughness and with reverence for character.

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(1) Out of the latest 1000 condidates for admission to the American Society of Civil Engineers in the three grades, member, associate member and junior, about 75 per cent. have graduated from a technical school; in the American Society of Mechanical Engineers, this proportion is 60 per cent.; in the Electrical Engineers, 44 per cent. In each society the proportion is largest among the junior members.

(2) Out of a catalogue of 55 technical books brought out by a leading American publisher of engineering books during the past year, 75 per cent. of the whole were by professors, mainly in Technical schools.

(3) See Presidential address of Sir Norman Lockyer, President of the British Association for the Advancement of Science, in September last, entitled "The Influence of Brain Power in History," devoted to urging the British Nation to come to the support of its Technical Schools.

(4) COST OF A BATTLESHIP.

The approximate cost of the hull of a first-class battleship is....	$3,250,000
The engines, machinery and engineering stores cost about......	1,300,000
For the largest ships the cost of armor is about................	1,750,000
For the largest ships the cost of armament is about............	1,050,000
The supplies and general equipment about......................	100,000
Total cost of a first-class battleship about...............	$7,450,000

For a ship of the Vermont class of 16,000 tons displacement, with the latest armament and including designs and superintendence, the total cost may approximate	$8,000,000

The cost of maintaining such a ship in commission will be nearly 50 per cent. more than for the three ships as stated below, which are of 12,000 tons.

The report of the Secretary of the Navy shows that the cost of maintaining the three battleships, Alabama, Kearsarge and Wisconsin, in commission for the year ending June 30, 1902, averaged	$441,248
Current repairs	30,914
Total	$472,162
The foregoing includes pay of officers, crew and marines, and cost of stores, including coal, but includes no allowance for depreciation. If depreciation be figured at the moderate rate of 5 per cent. annually, having regard to wear, and to improvements rendering much obsolete, this adds per year nearly	400,000
	$872,162

COST OF A TECHNICAL SCHOOL.

Several of the leading schools of applied science are parts of great universities in which the accounts of different departments are so merged that it is difficult to separate the cost of plant and running expenses required for the courses in applied science.

The Massachusetts Institute of Technology is perhaps the most convenient example for present purposes, because of being almost exclusively a technical school. Its present site is on land of exceptionally high value for business purposes, because of surrounding developments; therefore, I will not include the full sum for which this land could probably be sold.

It is estimated that a suitable site could be procured for	$250,000
The estimated cost of replacing present buildings at present prices is	1,044,000
The total value of apparatus and furnishings, as estimated for insurance purposes, is	386,000
Approximate cost of duplicating plant	$1,680,000
The endowment or stock, bonds and real estate producing direct income is about	1,150,000
Total	$2,830,000

The number of students is 1528.

The annual expenditure last year in round numbers was as follows:

Salaries	$320,000
Fuel	25,000
Water, gas and electricity	7,600
Repairs	16,000
Printing lecture notes, catalogues, etc.	14,000
Laboratory supplies and libraries	50,000
General supplies and maintenance	30,000
Miscellaneous	13,000
Total	$475,000

This amounts to an actual expenditure of about................	$311
per student (including special students, some of whom take few studies and pay less than full fee). Reckoning the interest at 4 per cent. and depreciation on whole plant, buildings and furnishings, at 5 per cent. per annum, this adds about..	91
making the total yearly cost per student......................	$402
of which he pays a tuition of $250.	

(5) The generous support given by Michigan, Wisconsin, and California to their great State Universities, which are coming to be in large proportion schools of applied science, may indicate a better appreciation of this service to the State than is yet found in the legislatures of our Eastern commonwealths, or than is yet disseminated through the mass of their intelligent citizens.

In 1903, Michigan paid from the State Treasury for the support of the State University		$559,835.03
The State raises by general taxation in the average year for the support of the State University	394,625	
and in addition makes special appropriations or draws from accumulated funds.		
Wisconsin raised by direct taxation for the support of its State University	289,000	
and when the regular annual appropriation is found insufficient the Legislature makes special appropriation. The entire disbursements on account of the State University last year amounted to	771,053	
The University of California has an income for current expenses for 1904-05 of..		659,808.96
of which sum nearly ⅓ is appropriated for departments in which engineering students predominate.		

The Case School of Applied Science is not assisted from general taxation, but depends for support only on the income from its endowment and fees of students.

(6) A locomotive engine of the type used in drawing the 20th Century over the New York Central portion of the route has, under test, shown a continuous development of upward of 1200 horse power, at speeds of from 40 to 57 miles per hour.

From a large type of locomotive, recently put in service on the New York Central and Hudson River Railroad, an indicated horse power of approximately 2000 has been obtained.

On the Lake Shore road, indicator cards, taken from fast passenger trains at one minute intervals for an entire trip where the speed over an entire division averaged about the same as for the 20th Century Express, namely, 54 miles an hour, showed an average of about 1000 horse power for the entire division. For distances of 5 to 10 miles, powers as high as 1500 to 1600 horse power have been obtained.

	Horse Power.
(7) The total amount of water power now in use daily by the works located at Niagara is not far from....................	75,000
In addition to this, there are now generated at Niagara, and transmitted to Buffalo and other points, not far from..............	25,000

	Horse Power.
The aggregate capacity of the generators installed up to date at Niagara is about..........	130,000
On the American side an additional capacity is being provided of perhaps	50,000
And on the Canadian site the contracts have been let for machines capable of generating about	80,000
In the city of Cleveland an approximate estimate, reasonably made up by Mr. Ambrose Swasey and Mr. Scovill, vice-president of the Cleveland Electric Illuminating Co., puts it at..........	50,000
for the total of the large electric power and electric railroad plants.	
At the 73 large factories in Cleveland, they estimate the power used as	85,000
In small factories, lumber yards, office buildings, etc., etc., probably	25,000
Total	160,000

ASSOCIATION OF ENGINEERING SOCIETIES.

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THE PRESENT AND THE FUTURE OF ENGINEERING ON THE PACIFIC COAST.

Inaugural Address.

DELIVERED BY PRESIDENT GEORGE W. DICKIE BEFORE THE SPRING MEETING OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST, MAY 26, 1904.*

Ladies and Gentlemen and Members of the Society:

WITH the hope that I might be able to help this Society in some of the problems that it will have to face in the near future, I consented, after a long rest, to again serve you as presiding officer at your meetings.

It is a great honor to be selected by one's professional brethren to be President of such a Society, and I appreciate to the full the confidence that you still have in my ability to serve you again in this capacity. It has come to be a custom in societies like this for the President, at the beginning of his term, to address the members of his Society on the general condition and future prospects of the profession that the Society represents; and, as the engineering profession in its various branches will best represent the varied interests of our members, I cannot do better on this occasion than to give you my impression in a general way on the present and future of engineering on the Pacific Coast.

I sometimes think that it has been unfortunate for the engineers who came to the Pacific Coast in the early days of its development that so much of their work both in the civil and mechanical branches of the profession had of necessity to be of a temporary character and executed under conditions and in localities that ren-

* Manuscript received June 30, 1904.—Secretary, Ass'n of Eng. Socs.

dered any extended knowledge of its character well-nigh impossible. If we could have a history of the engineering work carried out in California and Nevada during the 20 years between 1865 and 1885, it would be a remarkable record of daring work, and would lift into fame many names now almost forgotten. It is a great misfortune that the lust for gold overcame all desire to preserve a record of the work done by the men who made the search for the precious metal possible. Even the destruction of some fair parts of our State required engineering work of the most daring character in impounding water (the great agent of destruction), carrying it through mountains and across deep gulches, sometimes with the water under enormous heads, in order to bring it to the great beds of gold-bearing ground, where its force would sweep the accumulations of ages into the great sluices arranged by the miner to catch the golden treasure that Nature had locked up in mountain safes by the gentler acting of the same power that the engineer employed to crack these safes of hers. But Nature did no deep mining to get that gold that she locked up in the soil—that soil had been washed down from the mountains, and the gold had come with it and man must find its source, so he must mine to find the strata that contains the precious metal. The engineer must provide the means to do so. Hoisting engines and pumping engines and many other machines must be devised to explore the deep storehouses of Nature and bring the treasure to the surface, and some of the greatest works of this character were carried out during the seventies on the great Comstock Lode. Then engineering skill and chemical science had to combine their resources to extract from this precious ore the treasure it contained, and, although this work was all done within the life experience of several of our own members, no true history of it can ever be written.

This blank in the most interesting period of engineering history on the Pacific Coast is, I think, a great misfortune which can never be remedied; and, in order that it may not be repeated in the present and future work of the engineer here, the members of this Society should tell each other what they are doing and how they are doing it at such meetings as this, so that the record may be complete, and the great communities that are to occupy this land that we are trying to make pleasant and comfortable for them may know to whom they are indebted for the many conveniences of civilization they will find here, provided through the skill and labor of the engineers who are now making things ready for them.

Much of an engineering character that is going on now on the Pacific Coast is unknown to the profession outside of those within

sight of the work being done or directly concerned in the financial or engineering problems involved. The result of this is that the engineer and his work on the Pacific Coast are unknown to the world at large. In the transactions of the great engineering societies, or in the magazine literature of the profession, we can study the great engineering works being carried out in other parts of the world, but we do not appear to find time or opportunity to tell the world outside what we are doing here to utilize the vast natural resources around us. In this we are not dealing honestly either with ourselves or our professional brethren in other lands. While a number of us may be members of the National Engineering Societies, our isolated position makes it impossible for us to attend their meetings except perhaps once or twice in a lifetime, and in consequence we cut no figure in their transactions. We must therefore make the literature that will represent to the great world outside the work done by the engineers of the Pacific Coast. At present we do not know what we have done, what we are now doing or what we expect to do. It is therefore of the utmost importance to ourselves and a duty we owe to those who are to follow after us, that we meet together, from time to time, so that we may get to know each other, and compare notes as to what we are doing, thereby helping one another in the solution of the ever-present difficulties in all engineering problems. "As iron sharpeneth iron, so a man sharpeneth the countenance of his friend."

To my mind, one of the best reasons why the engineers of the Pacific Coast should maintain and foster a strong local Society embracing the different branches of the profession lies in the fact that the work done here is in many cases original both in conception and execution. The physical conditions on the Pacific Coast differ so widely from those of other parts of this country that the engineer must adopt special methods to meet these conditions, and the methods adopted and the conditions to be met are matters of great interest to engineers the world over. Our engineers should record their experiences in dealing with them in the transactions of the Society that represents them to the world. This, of course, requires meetings like the present to give the opportunity to the members to present either their written or spoken experiences and printed transactions to carry them to the outside world, but to make this machinery effective much is needed on the part of the members. There must be the habit of careful observation and the ability to record observations in words that will enable another, who has not had the opportunity to observe, to understand. There must also be a willingness to sacrifice present ease and comfort in order to secure

recognition from fellow-workers in the same profession. It often requires the sacrifice of many comforts and enjoyments to sit down of an evening and record the experiences of the day that are oftentimes very disheartening, but which might save a like experience to some other engineer in the solution of a similar problem. It is so much easier to forget those troubles than to record them, but the engineer, like others who aspire to high positions, must come to his kingdom through much tribulation, and it is only through having a record of the battle that the victor is known. There must also be a spirit of unselfishness on the part of those in control of large engineering undertakings. They should remove all obstacles which would prevent their engineer from giving to the profession the benefit of the experience he has acquired in their service. Obstacles of this character are to a large extent responsible for the meager character of the engineering records of work done on the Pacific Coast. This policy is not only selfish but in the long run most decidedly unprofitable. I think, however, that we are improving in this respect, and will continue to gather wisdom on this point as we grow older.

The engineering work now being carried out on this coast is beginning to be of a different character from that which used to characterize the work of the engineer. The permanent is taking the place of the temporary, which means that men of known ability will be in charge of such work, plans will be more carefully considered and by more experienced men than hitherto, and this is another reason why engineers should make their work known through such Societies as this, for what a man has done successfully will become more and more the measure of what he can do. We have many able engineers in the various branches of the profession here, some of them well known beyond the boundaries of the Pacific Coast, and there are many just as able who are not known. These men have been hiding their talents under a bushel. They may think that it is modesty on their part, but in most cases it is indifference, which is quite another thing.

We have each been so absorbed in our own little engineering problems that we have failed to notice the growth of things about us. The opportunities for engineers to take their part in the development of the varied resources of the Pacific Coast have been steadily increasing, until now the field is a broad and attractive one, inviting us to take a hasty glance at what it offers to the men now preparing themselves to stamp their characters on some part of it.

In railroad engineering, always a large factor in the development of a country, we have already done much, but what has been

done is only the beginning of what is ultimately to be a marvelous system of transportation, affording unlimited opportunity for engineering skill. The railroad engineers who planned the steel highways that have opened the beauties and riches of the Pacific Coast to mankind have left many traces of their skill amid the high Sierras that form our eastern bulwark, but these engineers have left little or no trace of their work in the annals of engineering. It is very unfortunate that this is so, for the past record of railroad engineering on the Pacific Coast, had it been preserved in the records of a Society like this, would have been a bright chapter in engineering experience. The temporary ways of the past are fast becoming the permanent ways of the future, as regards our railroads, and grand opportunities are to be afforded to the railroad engineers of the future. The mechanical engineer as well as the civil engineer will have his opportunity in the railroad development. Radical changes in the motive power are beginning to be felt as a necessity, and we seem to be on the verge of some great surprise in this field of engineering, whether this is to come from improvements in the present type of prime movers at the heads of trains, or through discarding the locomotive altogether and adopting some system of power stations where mountain torrents will be converted into electric energy to be applied by some new system to the railroad cars, cannot perhaps now be predicted, but I feel sure that some such change is in the near future. The younger member of the railroad family, the trolley car, though quite young, has had a remarkable growth, and who can tell what its future will be and what a field for engineering there is in its development. All branches of engineering are enlisted in the work of advancing this system of transportation—the civil engineer in finding a way and making it permanent, the mechanical engineer in devising and putting in operation the engines and generators (which are fast getting to be works of great magnitude), and the electrical engineer in designing generators to convert great units of power into electric energy and means for transmitting it to transforming houses and thence to the car lines. It might almost be said that a new science has been created to satisfy the demands of the electric railroad. Here, the engineer has a field to work in that is almost virgin soil, and that field on the Pacific Coast is even now a wide one and its possibilities very great.

The development of water power on the Pacific Coast, which has already made creditable progress, is, I believe, destined to be one of the leading factors in the future prosperity of this State. Some notable examples of this class of engineering have already been successfully carried out, and the technical history of these undertakings

should now be in our Transactions if the able engineers in charge of them would have given the time necessary to preserve the record of their own work, of which, I am sure, they need not be ashamed. Perhaps no section of the world's surface is better adapted to the utilization of water power than the Pacific Coast, with a background of mountains facing fertile valleys for more than a thousand miles in length and with streams rushing down the mountain sides at convenient intervals, having water heads as great as the mechanical engineer cares to deal with. If what has already been done in this branch of engineering on the Pacific Coast had been suitably recorded and illustrated in our Transactions, it would have enriched our records and made them a fit legacy for those who are to complete the work of conserving and converting into useful work the melted snows of our mountains on their way down to the valleys, where having lost their head by the way they may finally give their body to enrich the soil. There is no limit to the engineering possibilities in this department of applied science, and, in order that the Technical Society may have its share in the grand result, its members must bring their schemes and experience gained in working them out before their fellow-members, thereby insuring recognition both for the work and the worker.

A kindred subject to the utilization of our water power resources is that of the direct application of steam to turbine wheels, which is now threatening the long-established supremacy of the reciprocating engine. Neglecting the claims of Hero of Alexandria, dating back some 2000 years, we may say that the practical steam turbine is but a thing of yesterday, as it has not reached its majority yet as against the 200 years of the steam engine. It would be useless to conjecture what the prime mover may be 100 years from now, but there is little doubt that in the near future the infant steam turbine will, for many purposes, be a strong competitor with the maturely aged reciprocating engine. The steam turbine has already demonstrated the possibility of a working economy equal to the most advanced type of reciprocating engine, and great progress has been made in overcoming the mechanical difficulties of the problem. Hitherto we have been more interested in producing water wheels than steam wheels, but if the Pacific Coast should in the future do as much for steam wheels as it has done for water wheels, we will have an honorable share in the perfecting of this new steam motor.

In the developing of our natural harbor facilities, and creating artificial harbors where Nature has neglected to provide such facilities for commerce, there is a great and growing field for the civil engineer on the Pacific Coast. The day has about passed when tem-

porary harbor work will be accepted. Permanent works will be demanded and engineers competent to meet the demand will be required. The western edge of the United States is destined to play an important part in the commercial future of the Pacific Ocean, and present indications point to that future being big with possibilities which to-morrow may be probabilities and the next day actualities. Technical men will bring about this wonderful development, which will come more rapidly than even the most sanguine of us expect.

This country has now committed itself to building a canal through the attenuated waist of the continent, and one of the members of this Society has been given a place on the Commission to carry out this great work. We feel proud of this honor, and I have no doubt that when this great undertaking is complete the wisdom of this choice will be manifest. In the meantime this appointment ought to encourage every engineer on this coast and lead to a desire on the part of everyone in the profession to let his work be known and discussed, as thereby he will bring about a recognition of himself.

I trust that the success of this gathering of technical men will encourage the Society in this new venture, and that the members will not only look forward to the enjoyment of such meetings, but will prepare for and bring to them the very best things they have gathered in their professional work and experience. Professional men can benefit themselves and their professional brethren greatly by bringing their work, and especially their difficulties, before each other for discussion. No one can impart to another his experience, but the telling of it may suggest a field where we might work out some new experience for ourselves.

Experience is the principal stock in trade of the engineer, and Pacific Coast experience differs from all other engineering experience. The world should therefore know that quite a fund of it has been collected by the professional men here, and while it is an individual asset of him who has gained it, I would not like to have you think that I had little faith in any other teaching than that of one's own experience. You must not let any such impression be made on your minds by anything I may say on engineering experience, for anything I may say had better not be said at all than that it should have such an effect. I had not in my younger days the opportunity to learn all the recorded experience of the best thinkers in my profession, as many of you have had, and I sometimes think that many a dark passage in my book of experience had been spared me if I had had such opportunities. You will understand, therefore,

that when I speak of engineering experience I do not mean to say that that is the sum of all that an engineer ought to know, for the lessons to be learned in the school of experience will come easier and sooner to the man who builds his experience on a broad foundation extending deep into the accumulated experience of the profession.

I cannot tell you anything, to-night, of my own experience as an engineer, for the very good reason that there seems to be some impediment between one mind and another that prevents one man imparting his experience to another. We can speak about experience and the necessity of having it, but we cannot impart it to each other. There is plenty of it all around us, but each must gather it for himself, and does not always get the kind he thought was coming to him.

What, then, is the thing or quality of mind that men call experience? It is, I think, the formative or molding effect upon the mind of all the thoughts that pass through it from within, and all the impressions received by it from without, relative to the work with which our lives are identified; and the mind becomes rich in experience in proportion to the concentration of thought within and the strength of the impressions from without in regard to the matters we desire to become experienced in.

Memory, I think, must be a powerful mental factor in experience; in fact, the man of experience is such by virtue of the store of impressions he has gathered and arranged in his mental storehouse in such order as to be readily produced at the moment when their evidence is required to decide his course of action in regard to the subject to which these impressions relate. When a plan or design for any engineering work is presented to an experienced engineer for his opinion as to its merits or practicability from an engineering or commercial standpoint, a series of pictures at once present themselves to his mind. Mental photographs, as it were, of similar works, or works of the same character that he has been connected with in the past—where they succeeded and where they failed—are clearly pictured to his mental vision, so that he will be able to readily compare these pictures in his mind with the proposed plans before him; and as the pictures of failure or success most nearly coincide with the plans before him, so will his opinion be. This is experience, and it is the quality in an engineer that commands the highest price in the engineering market.

The brilliant young man who has been nursed at the public breast of recorded experimental data, but without any experience of his own, is often skeptical in regard to the experience of older men in

the profession. He considers engineering as an exact science, and that all problems in engineering are capable of demonstration, and that if the past work of any engineer had been carefully figured out in all its details by the methods he has learned to understand so thoroughly, these mental impressions I have referred to, so far as they represent finished results, would simply all be brilliant pictures of success.

I have no doubt about engineering being an exact science, but the engineer has not yet discovered the exact way to apply the science of engineering to the ever-shifting conditions under which he must do his work. His most careful and exactly figured-out designs sometimes surprise him by utter failure, while another design, under quite as difficult conditions, that he has given less time and thought to, may equally surprise him by its complete success. The static laws and dynamic forces in his most carefully planned machines sometimes get into most fatal misunderstandings with each other, and he stands puzzled amid the mechanical wreck without any satisfactory reason furnished by the result to show why the thing that figured out so exactly right should be so hopelessly wrong. But if he is a wise man the impression will not be lost, and will always be ready whenever his opinion is required on a class of mechanism of which this picture is a type.

Did you ever observe the difference in appearance between a piece of mechanism designed on scientific principles, with every part figured out to stand the strain that theoretically should come upon it, every journal having just the proper amount of surface for the load, and another piece of mechanism for the same duty, but developed by experience with the working of many predecessors? No scientific reasons could be given for the forms that certain parts had developed into, except that they would not work satisfactorily in any other form. It is not safe for any engineer to look upon general practice as the result of lack of knowledge. In all our designs we are on dangerous ground when we neglect the teaching of general experience. I have said something about engineering being an exact science; this is true only in part. The laws that govern bodies in motion and at rest, the expansion of gases, the conservation of heat and energy, are all exact in their operation, and the same conditions will always produce the same results. But the engineer has to apply these laws and forces through materials, used in the construction of the work he designs, that are varying in their qualities of strength and endurance, and what will behave satisfactorily at one time may utterly fail at another time, when to all appearances the conditions are the same.

Two metal surfaces may work on each other as a journal and bearing with perfect results at one time, leading you to believe that you had reached the desired end of your search for a satisfactory bearing metal; yet when you duplicate it under apparently the same conditions, the result is a disappointment, showing that your first experience, though successful, was very near a failure, only you did not know it. This is why an experienced engineer will sometimes not repeat work that those not in his confidence may have considered a great success.

This illustrates what I mean by saying that no man can impart his experience to another, as it is acquired for his own use only. If we were to be guided by another's experience, progress would be at an end in certain directions. Men have found by experience that certain things could not be done, because they have tried and failed to do them, and this experience was enough for them. They may also have given the world the benefit of their experience, telling others that such things could not be accomplished, because they had tried and failed; yet other men searching for an experience for themselves will try and do those very things that could not be done, and do them successfully, and thus gather an experience that contradicts that of the other. And this process goes on continually. What my experience tells me will fail, another's experience tells him will succeed, and yet my own experience must guide me, and not that of another.

Experience is a thing of slow growth, for often the first impressions produced by our work have to be modified as certain tendencies on the part of the work develop. This is especially true of moving mechanism. An engine or machine may make a fine start, engineering experts may give good reports in regard to it, and the designer may feel justly proud of the result of his labor; but by and by certain tendencies begin to manifest themselves; workmen are employed nearly every night to keep it in condition to run in working hours, but the fatal tendencies keep developing, until the machine is broken in constitution and is no longer fit for duty and must be abandoned. This is the end of many a fair start; and alas! how many of the model engines and machines that get conspicuous illustration and description in engineering publications come to just such an end, while other machines that required careful nursing at the start have developed constitutional strength that enabled them to serve their day and generation with credit.

I have found it very instructive to go back 10 or 20 years and study the designs for engines and other machinery that figured in the engineering papers and magazines, and that were advertised at

the time as the result of the best experience of the people who made them, and trace them on through succeeding years, noting how many of those receiving the highest commendations drop out of existence altogether, experience having shown them to be constitutionally defective; while others having sound constitutions as a foundation for development appear again and again, modified to suit varied conditions, but still showing through all changes the good stock from which they sprung.

Our own experience must be the result of wider observation than the limited horizon of our own work. We must make careful studies of other men's work. We cannot get their experience, but we can test our observations of what others do by an experience of what we have done in the same line ourselves, and thus enrich and broaden our ideas of the possibilities within the branch of engineering in which we have chosen to labor.

It should be the aim of every engineer to make himself an ever-growing power in his profession. This he can only do by continually increasing his resources, by carefully hoarding every item of experience that comes to him, either through failures or successes; both must often come to the man who leads a busy life in our progressive profession.

It is not at all necessary to parade our mistakes, even before the Technical Society. These lessons are for ourselves only; others may have to pay for them, but the profit should be ours. It is the duty of every engineer to hide his mistakes as far as possible; he should be the first to discover them and the most qualified to correct them, and, above all, he should be the last to forget them, for the memory of them is his experience.

Individual experience is a growth, beginning with the first child effort to make something and the impression that product made on the young mind that produced it, showing the direction in which a better thing might be made, the thing produced giving the mental stimulus for the next and higher production; and thus should our experience grow richer and stronger as our lifework advances. Careful observation of the things we have made, performing the functions for which we made them, enables us to make better things in the future, having more varied functions. It is the man who is most critical of his own work that becomes the man of rich experience. We must get on very intimate terms with our own work if it is to be the mine from which we are to dig the experience that will make us a power in our profession.

Some young men think when they have taken a course in engineering at a university that that should give them a place in the

profession, but that is not so. The fact that they have learned something of engineering at a university places them under great obligations to the profession, for they have been receiving out of the accumulated store, gathered by the best men of the past; and it is not what one gets, but what one gives to the profession that will make him a place among its honest members; nor can he borrow what he gives—it must be his own honest work. Therefore, I would say to the young men who are trying to find an honorable place among engineers: Don't go around seeking for friends to get you a place, but make up your minds what place you would like, and don't be afraid to make it high enough. Then to work! no matter how distant that work may be from the place you aspire to, if it points in that direction. Stick to it; don't waste time consulting with friends about your prospects and seeking introductions to people who will help you to the place you desire to reach, but make a close friend of your work—your best advice and surest advancement will come from it. Study the results of your work while others are seeking influence; put these results in the clearest language you can command and bring it to the Technical Society. Let no tendency in your line of work escape you. Feed your experience by close observation, and some day someone will want something done for which your experience is absolutely indispensable. You will need no one to introduce you to that man; he will search for you and be very glad when he finds you; and your place among engineers will be the very place you selected and worked to prepare yourself for, and which will be yours by right, and not by influence.

My dear friends, I doubt whether I have succeeded in giving you a satisfactory inaugural address. It is difficult to convey in words what I know engineering experience to be. I will be satisfied if I have succeeded in impressing, especially, our younger members, with the importance of acquiring experience as opportunity enables you to do so; considering your work, not the fruit of your life, but the planting, from which you and others are to gather in time the rich fruit of experience. For I promise you that he who thus utilizes all the work that goes through his hands will not fail to find the place he desires among the engineers of his time.

THE LAYING OF THE COMMERCIAL PACIFIC CABLE.

By Frank P. Medina, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 26, 1904.]

The design, construction, laying and maintenance of a long submarine telegraph cable involve scientific processes of considerable exactness and complexity and engineering work of much skill. The problems of design include some of a mechanical nature, which, in the present state of our knowledge, are usually simple; and some of an electrical character, which are rather more abstruse and difficult. The cable must have sufficient tensile strength to permit it to be safely laid in very deep water, and to be picked up should it become necessary; and, since its cost is very great, it must have a correspondingly long life. There must be a central conductor, consisting of a single group of copper wires, usually composed of 7 separate strands (11 in the Pacific cable), and these are covered by a coating of insulating material, for which nothing has been found so well adapted as gutta-percha. The conductor must be of sufficient conductivity and the insulator of sufficient resistance, and have just the right amount of inductive capacity to enable the specified number of words per minute to be transmitted. These considerations suggest some of the problems of design. The laying of the cable calls for a survey of the projected route and a detailed knowledge of the soundings thereon, a specially constructed ship having adapted tanks for storing the cable, and special apparatus on board ship for paying it out and testing its continuity and resistance during the laying. Its maintenance calls for means of locating faults and of grappling and raising the cable to the repair ship, and apparatus for uniting conductor, insulator and armor. Its operation demands very sensitive recording instruments, since only a very small proportion of the total energy used in signaling is available for useful work.

It is the object of this paper to touch on some of the points of design and construction, laying and maintenance of submarine cables, with special reference to the Commercial Pacific Cable Company's cable between San Francisco and Manila, the laying of which was completed on the 4th day of July, 1903.

The specification for cables usually prescribes that they shall carry a given number of words per minute, by the hand signaling method, which number in the case of the Commercial Pacific Cable Company's cable was 28 words. The speed of signaling in sub-

marine cables is inversely proportional to the resistance of the conductor and the electrostatic capacity of the insulator. The product of the capacity K into the resistance R, the former measured in microfarads and the latter in ohms, is a measure of the time it takes an impulse wave to rise and fall between its lowest and highest values, and the K R is a constant for each cable. For cables of given conductivity and capacity per unit of length, the time of such rise and fall of impulse waves varies as the square of the length of the cable; for both K and R increase directly as the length increases.

Existing cables supply the data for applying the K R law to a proposed new cable. The capacity per knot in microfarads into the copper resistance in ohms of the datum cable furnishes a coefficient which, multiplied into the ratio of words per minute of the datum cable, to the words per minute required in the new cable, and into the square of the ratio of the length of the datum cable to the length of the new cable, gives the required K R of the new cable.

From the K R thus derived the size of the copper conductor and the thickness of the insulation are calculated. A gutta-percha resistance between 3000 to 7000 megohms per knot after 1 minute's electrification is chosen, for the reason that a higher insulation retards the speed of working, because too much of the discharge of the cable has to leave at the extreme ends instead of leaking through, and because a lower insulation affects the stability of the gutta-percha. The calculations must be made with reference to the fact that the insulation resistance of gutta-percha increases with pressure due to the depth of the water in which it lies and with fall of temperature. The variation due to pressure has been determined at 61¼ per cent. per 1000 fathoms depth. The variation due to temperature, as observed by experiments on the Persian Gulf cable of 1863 and the French Atlantic cable of 1869, showed that the change in resistance between 75° F., at which the factory tests were made, and 53° F., the temperature of the experimental tests, was 3.912 to 5.042 times as great.

The temperature of the sea bottom between San Francisco and Honolulu, like that of the North Atlantic, averages about 35° F., and the mean depth is about 2500 fathoms, with a maximum of 3073; between Honolulu and Midway Island the mean depth is 2000, with a maximum of 3026; between Midway and Guam the mean depth is 2600, with a maximum of 4900, and with sudden and great fluctuations; and from Guam to Luzon the mean depth is 2200, the maximum being 3400.

Such was the problem that had to be worked out by the India-

Rubber and Gutta-Percha Telegraph Works, of London, and by the Telegraph Construction and Maintenance Company, to whom the contracts for constructing and laying the cable were awarded. The speed was to be 28 words or 140 letters per minute.

In its length of 8300 nautical miles, the copper conductor weighed 3,600,000 pounds, the gutta-percha insulation 2,310,000 pounds. The conductor and insulator form the core, outside of which is a cushion of jute yarn weighing 2,010,000 pounds, and between this cushion and the core is a brass sheathing in the form of a tape, to protect the gutta-percha from the teredo and other marine borers. This sheathing weighs 52,000 pounds. Outside the jute cushion an armor of iron and steel wires gives it tensile strength and resists mechanical injury, and this armor weighs 19,000,000 pounds. The armor is covered with preservative tapes, of which there are 306,000,000 yards, the compounds on which weigh 4,220,000 pounds. The diameter of the copper conductor is 0.1801 and the thickness of the insulation is 0.2417. The outside diameter of the deep-sea cable is 0.936. But the shore ends of cables are always much larger, being much more heavily armored, to protect the cable from dragging anchors and resist the constant wearing action of the tides. The shore end of the Commercial Pacific cable is 2.4 inches in diameter.

The reason for giving the contract for the construction of the Pacific cable to a foreign company was the lack of sufficiently high development of the art of submarine cable manufacture in this country. The risks of failure were so great, and the penalty for failure so serious, that nothing short of the skill and experience which English manufacturers had gained during years of practice was deemed available.

The armor is composed of steel and homogeneous iron wires, the elongation being about the same in each; that is, about 5 per cent. The total weight of deep-sea cables is about $1\frac{1}{2}$ to 2 tons per knot, but shore ends weigh 15 to 20 tons.

When the San Francisco-Honolulu end of the cable was completed in the factory, it was run on board the ship "Silvertown" and coiled in tanks in her hold. This coiling is carefully done with reference to keeping the ship in trim, each tank being filled to $\frac{1}{2}$ to $\frac{2}{3}$ its capacity. Any want of trim is corrected by filling the necessary water ballast tanks. The coiling takes place from the outside circle of the tank inward to a central conical core, and when the innermost turn of 1 flake is laid next this core the cable is taken back straight across the turns and coiling from the outside recommences.

You will probably recall the arrival and departure of the

"Silvertown" on her expedition with the San Francisco-Honolulu section on board. She is 350 feet long, 55 feet broad, 34 feet 6 inches deep, and fitted with engines of 1800 horse power, steaming at a speed of $10\frac{1}{2}$ knots, with a coal consumption of 30 tons per day. She carries 3 tanks, 32 feet in depth, the largest being 53 feet in diameter.

The landing of shore ends is usually accomplished by loading the cable on lighters. For the Pacific cable, the landing of the San Francisco end was done by unloading several miles on a steam schooner, the great draught of the "Silvertown" compelling her to lay too far out to permit of dragging the cable to the beach directly, even when supported by balloon buoys. But the schooner was enabled to come inside the San Francisco sand bar, which skirts the Cliff House beach, and the shore end was duly landed and carried to the cable house, just back of the Life-Saving Station, in a trench running therefrom to low-water mark.

The schooner proceeded to pay out the shore end as she steamed to the "Silvertown," when the remainder of the cable was coiled on board, and being spliced to the coils in the tanks was carried by the "Silvertown" on her way.

The shore end is spliced to a piece of cable 2 miles in length, smaller than the shore end, but larger than the deep-sea cables; for there are usually 3 types of cable, as in the present case—a shore end, an intermediate and a deep-sea type. And when finally this intermediate end was spliced to the deep-sea end the voyage began in earnest.

Electrical communication is maintained between the ship and cable house at all times during the journey. Both on shipboard and on shore, the spot of light on the galvanometer scale is anxiously and continuously watched, to note the appearance of any sign of flaw as the cable sinks overboard. The electrical engineers watch for a momentary fluctuation of the light spot at intervals of five minutes, due to impulses transmitted from the far end, as this assures them of the continuity of the conductor; while the relatively quiet location of the light spot at zero at all other times shows the perfection of the insulator.

The cable is passed through a bell-mouth fastened across the hatch over the tank, and thence to the paying-out machinery. From the tank over leading pulleys it goes to the friction table, which is a device for applying a retarding strain instantly if needed. From the friction table it goes to the paying-out drum, round which 3 or 4 turns are taken, and thence to a dynamometer and over a stern sheave to the water.

The drum is provided with brake wheels, the friction on which can be adjusted by weights on the ends of levers in accordance with the conditions of depth, type of cable and speed of ship. A steam engine is also fitted, capable of being put in gear with the drum when required, as to haul cable inboard when a kink or fault has been paid out, or to haul up cable from the tank at starting.

Two brake wheels are mounted on the drum shaft, and have brake straps of stout iron carrying hard-wood blocks which bear truly on the surface of the wheels. Levers pivoted near the shaft operate the brakes. Each of the levers carries a vertical rod working in guides, and on these rods weights are placed in accordance with the power required. Means for readily loosening the brakes are provided, so that they can be thrown off whenever the dynamometer indicates an extraordinarily heavy, sudden strain.

The aim is to lay the cable along the bottom of the ocean without strain and without unnecessary slack. In 2900 fathoms, with the ship steaming at 8 knots an hour, 25 miles of cable are in suspension in the water. Two and one-half hours are occupied in such case by any particular point in the cable to sink to the bottom.

It is aimed to lay the cable along a route free from sudden elevations and depressions, and especially to avoid the craters of submarine extinct volcanoes. The soundings taken by the survey ships are usually of insufficient detail to guard against this, therefore a system of continuous soundings is kept up aboard the cable-laying ship. One of the instruments used in this service is the James submarine sentry, a kite-like device of wood, so attached to the sounding line that the speed of the vessel, resistance and line of impact of the water keep it constantly at a selected depth, until it strikes an obstruction, as a submarine mountain top, whereupon its kite-like connection with the sounding line is tripped, and it floats to the surface, a dead piece of wood on the end of a wire.

The chemical constitution of the ocean bed is also a matter that needs to be known, and is important as affecting the stability of the armor. Tubes are attached to the sounding line, and being equipped with suitable valves, bring up specimens of the bottom when the line is hauled in.

The San Francisco-Honolulu section of the Pacific cable was laid in 10 days, without troubles of note, until near the time for landing the shore end at Honolulu. When 35 miles off the Hawaiian coast a heavy storm appeared, which threatened to prevent the landing on Christmas day, 1902, the date for which the event had been scheduled; but, notwithstanding this untoward event, the landing was made nearly on time and the cable showed no fault.

If a fault had developed meantime, it would have been the first act of the engineers to make location tests ascertaining its position. These tests are made with galvanometers and accurately adjusted resistance coils, and, where the fault is a defect in the insulation, consists in discovering the resistance of the copper conductor between the end and the fault. The resistance per knot of the cable at a given temperature is already known, the mean temperature of the bottom in which the cable rests is also known, and therefore the galvanometers' indications are readily reducible to distances in knots, and the position of the faulty point ascertained by reference to a chart on which the whole cable has been plotted. But in making this location test, the fault itself forms part of the circuit; and as cable faults have a habit of varying their resistance between very wide limits, it is a matter of great nicety to tell just what is the copper resistance between the end and the fault. Various modes of doing it are used on single conductor cables; but where 2 conductors or 2 cables are available, so that a metallic loop can be formed, the fault being in one of the conductors only, accurate location tests are readily made, and variations of resistance in the fault are no longer a source of inaccuracy. With single conductors to deal with many tests are made from both shore ends, all the results being compared, those from each end being checked with those from the other, until an agreement is obtained, which shows the proximate position of the trouble.

Suppose a fault had developed some hundreds of miles back from Honolulu. The "Silvertown" would have had to return to the spot indicated by the engineer's tests, and by grappling would have had to bring the cable to the surface. In calculating the proper tensile strength to be given a cable, in order that it may stand this picking-up strain, it is usual to allow a factor of safety of 3 or 4.

Arriving at the indicated spot, observations for position are taken and a mark buoy anchored at the place. Proceeding a mile at right angles to the supposed direction of the cable, the ship, with dragging grapnel, sails back and forth across the line, until the cable is hooked. It is thereupon hauled aboard and cut, and the direction and distance of the fault from the ship determined by further tests. This matter being settled, the end of the perfect cable is buoyed and the end of the faulty cable carried through the picking-up gear to the tank, where it is kept in constant connection with the testing room.

The picking-up gear consists of a bow sheave, over which the cable is led to the steam-driven drum of the winding apparatus, whence it leads through guide sheaves to the bell-mouth over the

tank. There it is coiled about by attendants, as when first taken aboard ship.

The testing galvanometer is meantime being carefully watched for any change in deflections, as such change indicates a mechanical disturbance of the fault, and when the fault is finally brought on board the cable is once more cut, this time at a point beyond the fault, and the now perfect cable in the ocean is spliced to the piece in the tank.

The copper conductors are laid together by a scarf joint, soldered and wrapped with fine wire. The gutta-percha is then warmed at one side of this joint and drawn down over it. The other end of the gutta-percha covering is warmed and drawn down over the first layer, so as to inclose the copper completely. This makes a very thin covering over the conductor. At the middle of the joint a roll of gutta-percha tape is twined about the joint, and being warmed is spread to the right and left until it covers the whole joint. More perfect adhesion is effected by the use of a cement of gutta-percha and tar, called Chatterton's compound; and when the splice is completed it shows but very little larger than the other parts of the core.

The core being joined, the remainder of the cable wrappings and the armor are connected together, the cable thrown overboard and the ship sails back to the buoyed end, where the final splices are made.

This is what would have happened if a fault had developed during the "Silvertown's" voyage; but as it turned out there was no such mishap, and she made an average of 200 miles a day for the journey.

The contract for the sections of the cable between Honolulu and the Philippines had meantime been awarded to the Telegraph Construction and Maintenance Company. The cable ships "Colonia" and "Anglia" left London on the 9th and 10th of April, 1903, with the cable on board. The "Colonia" is the largest cable ship afloat, having a dead weight capacity of nearly 11,000 tons, with a capacity of 4000 knots of cable in her 4 tanks. The "Great Eastern" had not more than half this capacity. The dimensions of the "Anglia" are somewhat smaller.

The "Anglia" started from Manila on May 24th, arriving at Guam on June 2d. The "Colonia" had reached Guam on May 27th, and the engineering and electrical staffs from the "Anglia" were transferred to the larger ship, which proceeded on its journey to Midway, arriving on June 19th. At Midway, the "Anglia" joined

her, and reshipping the engineers, laid the remaining section of the cable to Honolulu, completing the work on July 4, 1903.

The maintenance of so many thousands of miles of submarine cable is matter of much expense and consideration. The shore ends are subject to injury from dragging anchors, and the armor is likely to be eroded by the action of the tides. Chemical action from substances contained in the sea bottom, the attacks of submarine borers, effects of submarine volcanic action and even the acts of the larger aquatic animals are sources of interruption which manifest themselves from time to time.

Weekly observations of the electrical condition of the conductor and insulator are taken, and accurate records kept thereof, to be used as data in locating faults.

Besides the dangers from submarine activities cited above, there is always a liability to injury from excessive current or electromotive force from the land ends, caused by lightning or stray power currents. Indirect working of the cable through condensers and careful fusing diminish this danger.

The great cost of long cables makes it very desirable to bring their working capacity up to the highest notch. As above stated, it is not practicable to work more than 1 conductor in cables over 500 miles in length, on account of their mutual interference with signaling; but it has become possible to practically double the carrying capacity of single conductors by working them on the duplex system, whereby 2 messages may be transmitted in opposite directions at the same time. The duplexing of cables of considerable length is a matter of great delicacy—much more delicate and difficult than duplexing land lines. The attempt to quadruplex long cables has been made, but without success.

As to the future of submarine telegraphy, now that we have a new system of communication through the atmosphere which does not use wires at all, I have only to say that the projectors of the Commercial Pacific cable had witnessed the best performances of the wave telegraphs before they began to lay their cable, and that these performances failed to stop them.

SIMPLE STEAM TURBINE ENGINES.

By John Richards, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 27, 1904.*]

I should perhaps apologize for presenting before the Society a paper of so elementary a nature as the one that follows; but it may be assumed that such papers are directed to two objects—the advancement of technical knowledge among the members and the furnishing of popular information on technical subjects. The present paper belongs mainly in the second category. It is devoted to a subject so new at this time, in a popular way at least, that its elementary character will be an advantage, especially as the scientific phase of the subject has had copious treatment at the hands of others.

It is a strange fact that the "evolution" of steam turbines is following a course quite the opposite of that of piston engines. In the latter, the constructive part was developed and in a great measure completed before the thermal or thermodynamic features were investigated and explained; and, as a matter of fact, ignoring the modern demands of increased speed and pressure, the constructive feature of such machines has not greatly advanced in recent times.

Some of Watt's steam engines remained in constant use for a century, and many old engines made in this country had a record of 50 years and more; but, as remarked, the thermal or thermodynamic features that pertain to the art have only in recent times become understood and applied. Thirty years past will include what may be called the scientific evolution of piston or pressure steam engines, and, with some exceptions, will include the development of their proportions and their arrangement into types.

In steam turbines, the scientific part has preceded the constructive one; in fact, was complete in essential points when their practical construction and use began. This was, of course, because all steam and heat engines are governed by the same general laws, with the difference that turbine or impulsive engines deal with the flow and gravity of steam instead of its pressure, and hence are more complicated in several respects, but, as before remarked, they follow certain ascertained laws which govern heat engines in general.

The problem of constructing turbine engines has, as may be claimed, only begun. Even the types are not yet determined, and

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no doubt many years will elapse before this branch can reach a successful evolution and constant types appear. Design and methods of construction must arise out of use and experience, and must be proved by the inexorable tests of efficiency, endurance, adaptation, economy and cost.

A principal fact, relating to turbine engines now in use, is that while this term is applied to all kinds of steam wheels driven by impact, reaction, or pressure of steam, there are two types that are quite distinct as articles of manufacture. One of these types I will call "single" acting, the other "stage" acting. These types are best known in common speech by the names of inventors who have in recent times been most prominent in their development; the single acting as the De Laval or Riedler type, the stage or double acting as the Parsons type. Another type, that will have some notice hereafter, is the reaction type, not commercially made at this time, but a "parent" of the whole, as will appear.

The two first named types of engines are also designated as impulse and pressure machines, but these terms do not very clearly define just what is meant; they are, however, as nearly descriptive as any that can be selected for the purpose. The action to be described in these cases will be better understood by saying that one operates by "push" and the other by "blows." One is free running or open, the other inclosed to maintain pressure.

Of steam turbines, those of the stage or Parsons type are at this time the most numerous and the best known, and they have engrossed the thought and skill of many able engineers. They correspond in many respects to inclosed or pressure water turbines of the Jonval, Fourneyron and centripetal types, which act mainly by "push" or pressure, but not by sustained pressure in the same way as in the action of pistons.

The stage or successive action of the steam in this type of engines has for its main object the reduction of speed and rate of revolution, thereby adapting the machines for coupling directly to pumps, dynamos, marine screws and so on. It also avoids the enormous centrifugal strain set up in single-action machines.

Turbines of the single-action or impulsive type are open and without maintained pressure, as in the tangential, Girard and other unfilled water wheels. Consequently they have no running joints to maintain against steam pressure.

Steam and water turbines being analogous in many of their features, and the latter being much better understood, especially on this coast, where water turbines of all kinds are employed, a comparison will aid in the present explanation.

The main distinction between steam and water turbines arises out of the different natures of the two fluids. One is elastic and light, the other inelastic and heavy. In the case of water the velocity of efflux is low and in proportion to its density, reaching a velocity of about 80 feet per second under a head of 100 feet, or a pressure of 43 pounds per square inch; but in steam the velocity is immensely greater. The velocity, in feet per second, of efflux from nozzles equals 60 times temperature in degrees Fahrenheit plus 460. This gives a velocity of 1680 feet per second for steam at a pressure of 100 pounds per inch; but this is much less than is now assigned for actual efflux from nozzles on which the speed of turbines must be computed. The practical velocity of turbine wheels is computed on a flow of 3000 to 4000 feet per second, and for the vanes from 1200 to 1500 feet per second, or 75,000 to 100,000 feet per minute.

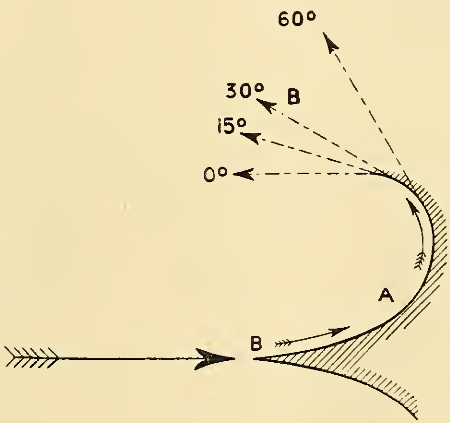


FIG. 1.

This is more than 12 times the rate of the fastest railway trains, and, as a physical fact, almost evades the power of conception.

Otherwise than as to the great difference in their velocity, steam and water turbines follow like laws; the spouting energy, as it is called, being theoretically equal to the gravity; or, in other words, the "blow" is equal to the "push," provided the kinetic energy of the impact or blow can be equally utilized.

The action of all unconfined liquids is expressed in an old rule (it may even be called a gospel) of fluid motors: The fluid must "enter without shock and leave without velocity." This rule, applied to any motor driven by the impulsive energy of a fluid, will determine the correctness of the machine's operation, or, as it is called, its efficiency, meaning the useful effect produced in proportion to the weight and velocity of the fluid consumed.

To further explain this action of fluids, if a stream is directed against a fixed flat surface, only a portion of the energy is imparted to the surface, about one-half in fact. The entry is a shock, and the fluid is scattered in a lateral direction with violence and leaves with velocity. If the same stream of fluid is directed tangentially into a curved vane or bucket, as in Fig. 1, and if its course is gradually reversed, it will leave with velocity, and that much of its energy will be lost; but if the bucket or vane A is set in motion with the fluid at one-half its velocity, then, by the component of these motions, the fluid will be brought to a state of rest, and will leave without velocity, the buckets receiving the total energy less fluid friction and some loss due to the divergence of the lines B. This is the manner of operating in all fluid motors of the impulse type or of single action.

The tangential entrance of the jet or stream and the resultant or discharge angle are very important features in practice, and will

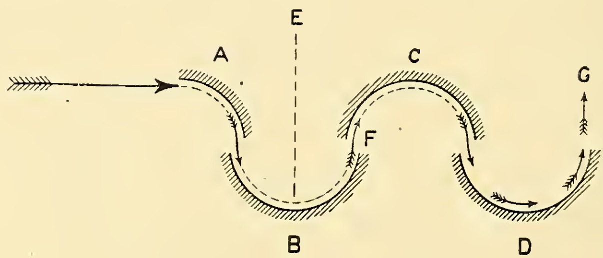


FIG. 2.

be again considered at some length, not in respect to economy alone, but as materially modifying construction in several ways.

Reverting now to the filled or pressure class of turbines for water or steam, these operate in a different manner, by what is commonly called pressure, but not pressure within the usual meaning of this term. "Obstructed flow" comes nearer describing the operation.

The course of the fluid through the machines is made so tortuous or difficult, by means of reversing or baffling curves or vanes, that the gravity or pressure of the fluid acts like a static force.

Fig. 2 illustrates, in an imperfect way, this action, the large arrow, in this as in other diagrams, being employed to show the line of impingement or course of the fluid.

If all the vanes or buckets, A, B and C, were fixed, it is clear that the water would be discharged at G with reduced velocity, even if it were confined; but if the vanes B are set in revolution in the

plane at E at half the velocity of the water, it will be left at F in a state of rest or without velocity. If the vanes B are set in revolution at one-fourth the velocity of the water, there will be a residual discharge of force at F, to enter the third set of vanes C, these latter revolving in an opposite direction, so the speed of rotation of any set of moving vanes will be reduced accordingly. If the vanes C are fixed, and discharge into a fourth set of vanes D, the rate of rotation can be reduced again as the square root of the water's velocity in the two cases. This is the manner in which the speed of stage turbines is reduced.

The vanes A and B may represent a common water turbine. With the vanes C fixed and those at B and D moving, we have a two-stage steam turbine, except that in all cases the buckets or vanes, whether for steam or water, are of ellipsoidal or other modified curves.

Water turbines of this class have commonly only two sets of buckets or vanes, A and B, for example, one fixed and the other movable. Stage steam turbines have from 5 to 10 sets of vanes, the mobility of the fluid demanding this difference. All motors of this class are called "filled," the induction and eduction passages being approximately of the same size in the case of water wheels, but increased, of course, for elastic fluids to accommodate their expanded volume.

One other class of motors remains to be noticed, viz: the reaction type. Their manner of operating will be more clearly explained later on.

These remarks will, I hope, explain the classes or types of steam turbine motors as now made and in course of evolution; and, with this much respecting the principle or mode of their operation, I will turn briefly to their history and afterward discuss the constructive problems, which, as at first explained, form the principal theme to be dealt with at this time.

It is common to begin the history of steam engines with an account of the "æolipile," made in Egypt about 2000 years ago, by Hero, a Roman architect. This device, with which almost every one is familiar, is illustrated by Fig. 3.

It is an organized steam motor, much better than some made at this day; and, considering the circumstances of the time, was a wonderful production, evincing, as it does, a knowledge of the expansive force of steam; also the principle of reaction. A is a rotative steam-containing vessel, B B are hollow arms delivering jets of steam tangential to the path of revolution C. Supposing the vessel A to be filled with steam from a pipe D at a pressure of 100

pounds per square inch and the area of each jet to be 0.1 inch, or together 0.4 inch, then the pressure on these orifices, if closed, would be 40 pounds. When open, there is no pressure on this area, but an unbalanced back pressure of 40 pounds in the opposite direction, the turning force, due to reaction or unbalanced pressure.

I am aware that a mathematical treatment of this matter would involve the ponderable matter discharged, its velocity and other intricate conditions; but the theory of unbalanced pressure will answer for present explanation.

This Hero wheel was a reaction turbine, and, as such, was a much more complicated and ingenious conception than the direct acting or impulsive wheel of Branca, which followed in 1629, about 800 years after Hero's æolipile.

This latter device can scarcely be considered an invention; but it must be remembered that the expansive force of steam was, even

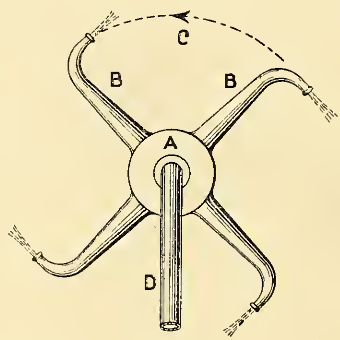


Fig. 3.

at that date, a mystery. No useful application of this device is known, and it was only a toy, consisting of a wheel with flat vanes against which a jet of steam impinged.

From this point the art seems confined to England, or mainly so, and from 1784 to 1901 there were granted in that country more than 400 patents for machines that may be classed as, or with, steam turbines. These various patents have been recently examined and listed by Mr. Robert M. Neilson, an engineer of Manchester, England, who has arranged a chronological list of them in a treatise on "Steam Turbines," published last year.

Even James Watt, John Ericsson, Perkins and other well-known steam engineers "had a try" at these obdurate machines without permanent result, and an inference, to be drawn from the copious array of schemes proposed, is that the principal impediments were in various operating conditions now better understood and

mainly the want of resources for constructing machines to move at such great velocity.

There is also the fact that, in so far as principles or modes of operating are concerned, these inventors anticipated about all that is known in the present steam turbine practice, except in the respects just named.

Kemplein's engine of 1774 was a reaction one, with the arms and vents as in the æolipile of Hero. James Watt's machine of 1784 was similar in operation, with this difference, that he proposed to vent the steam under mercury or other fluid. Sadler in 1791 devised a compound machine or one of double action, also of the reaction type. Trevethick in 1819 proposed a reaction machine, and John Ericsson in 1830 patented a very well-designed reaction wheel.

In 1843 Pilbrow patented a stage turbine with a large number of fixed and moving vanes or buckets arranged for expansion. Indeed, his machine had all the main features of modern engines of the stage type.

In 1848 Robert Wilson patented the first radial flow steam turbine, which in design fully anticipates the Dow and other radial flow machines of our time. He also proposed a parallel flow engine with expanding chambers or spaces, in the manner of Parsons.

In 1888 Alexander Morton, a well-known engineer of Glasgow, Scotland, made experiments with a steam turbine of ingenious form, and other inventors in Scotland made reaction machines that were said to be applied to practical work; but undoubtedly the principal part in the history of reaction engines was the invention of William Avery, of Western New York, who, about 1825, made and put in successful operation a large number of such engines.

Mr. Avery was a near relative of Prof. John E. Sweet, President of the Straight Line Engine Company, of Syracuse, New York, to whom I applied some time ago for information respecting the Avery engines. Professor Sweet replied as follows:

In respect to the history of the Avery engines, these were made 75 to 80 years ago by William Avery, a local mechanic here. There were about 50 constructed and put in use. One of the runners is now in my possession; another, that I saw years ago, had a hollow shaft of perhaps 1¼-inch bore. The head or runner was of sword shape, the arm 1 by 3 inches at the center and ⅜ by 3½ inches at the ends, the diameter swept being about 5 feet. Steam was admitted through the shaft by means of a stuffing box, passed through the shaft to the hollow arms and escaped at a tangential issue ⅛ inch by ¼inch, at the rear corners of each arm, the ends of which were stopped by plugs brazed in. Owing to the rapid rotation of the arms—10 to 15 miles per minute—the front edges were so rapidly cut away that replaceable blades made of tempered steel were inserted so they could be renewed. The fact that the engine had to be taken to a blacksmith shop every 3 or 4

months for renewal or repairs had more to do with their abandonment than their lack of economy. As to the latter, people who knew the facts, or claimed to do so, said that when they changed to the common slide-valve engines there was no gain in steam economy over the Avery engine.

Another feature that worked against the Avery engine was the stuffing box around the shaft, which in the hands of workmen of that time was apt to be set up so as to consume a large part of the power in friction. This was a natural consequence, as the wear was rapid. What the result would have been with a truly ground shaft in a metal bush, instead of a turned shaft and stuffing box, making the issues expanding nozzles and multiple expanding by 2 or 3 arms in separate cases and connecting to a condenser. is not known. It might rival a pretty good modern engine, if not the best.

The Avery engines were used in saw mills and woodworking shops of the time. They had weak starting power, and did not need much for the uses named. They ran at such a fearful speed that the reducing motion was an impediment. Mr. Avery had to employ bands, which were far more objectionable than gear wheels.

The Ruthven and also the Gorman engines of the same type are mentioned by Prof. Rankine in some of his writings and claimed as attaining an economy equal to piston engines of the time.

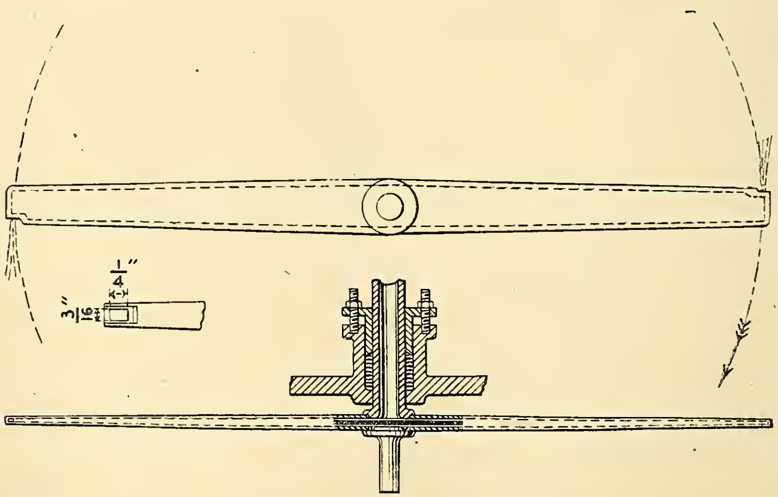


FIG. 4.

Professor Sweet sends, with his communication, a drawing of the Avery impeller in his possession. This is shown in Fig. 4, and it must be admitted that the circumstances described, as before remarked, form a principal fact in the history of free-running engines. The economy attained, even if there were no other fact than that of 50 or more engines being made and put into practical use, is enough to amaze one when it is considered that the engines were purely reactive like a Barker water wheel or the Hero engine in Fig. 3, and that the inert fluid under atmospheric pressure was left

directly in the path of the impeller's arms, and wore away the front part where the pieces were inserted. The casing was no doubt of a form to prevent free revolution of the spent steam, otherwise this impediment would to a great extent have been avoided.

This machine admits of further comment, especially in its constructive features, and I have no hesitation in claiming that the material is in this case better disposed to resist centrifugal strain than in any steam turbine now being made. The speed was no doubt equal to that of machines now constructed. The structure is not exposed to incomputable inherent strains, as continuous wheels or disks must be, and the box section, made of thin metal plates, is the strongest known in the arts.

In a letter received from Mr. Charles Brown, of Basel, in 1903, I find the following remarks respecting the Avery engine:

> Early in the forties an American engineer by the name of Pratt told me that he had experimented with two of Avery's Hero reaction wheels, one with 100 pounds steam running at 45,000 feet per minute. It gave 30.3 horse power and consumed 7½ pounds per horse-power hour, and another with 130 pounds steam giving 24½ horse power consumed 6.16 pounds running at 54,000 feet. Diameter at nozzles 5 feet. If these data are correct the result compares well with a 30 horse-power Laval, which, non-condensing, consumes fully as much coal as the old Avery. Pratt told me that Avery had built a locomotive with his wheel. Avery's engine had the advantage over the Laval that the number of revolutions, 2800 to 3600 per minutes, are so low that it might be used for driving many machines without the intervention of gearing, so that it might be worth while to take up the study of the Avery again, for the wear and tear of the Laval gearings is heavy. For heavy work, the Parsons is not likely to be superseded for some time yet. Brown, Bouverie & Co. are crowded with orders, and the works are in a chronic state of expansion; the large sizes are so much more economical that the piston people have no chance. Latest test gives 8 pounds per indicated horse-power hour.

The next step in practically applying the free-running steam wheel to useful purposes was, so far as I know, by Dr. De Laval, of Stockholm, Sweden. I was often in Sweden during the earlier experiments there, and imbibed a curiosity and interest in this matter that has lasted ever since, especially since coming in contact with the tangential type of water wheels on this coast. These latter are operated under pressures much greater than has been attempted with steam motors; that is, up to 900 pounds per inch, giving a velocity of 120 feet per second. I believe, and I shall attempt to show, that such wheels are made on a system much in advance of steam turbine practice in some very important respects.

Following Dr. De Laval and perhaps others in steam turbine wheels of single action, came a successful division into stages by Hon. A. C. Parsons, one of the most eminent steam engineers of our

time. This subdivision, it may be called, of the steam turbines, had for a principal object, as before pointed out, a reduction of the speed of wheels and their adaptation to direct driving of dynamos, marine pumps, screws and the like, offering uniform resistance or load.

Wheels or engines of this type involve the maintenance of running steam joints between the stages, and demand workmanship that is now and will likely remain a bar to their general manufacture. There is also an inability to endure lateral stress on the spindles, because the running steam joints that separate the stages of pressure have a clearance of about 0.01 inch. These latter features have confined the engines to purposes where simple torque is delivered, but this, includes a great part of the whole field of motive power.

Parsons's modification of these engines has called out scores of inventors and imitators in this and other countries, and it seemed for a time as though the De Laval engines were to remain sole representatives of the single-action system; but a reaction has began, most notably in Germany, where Professor Riedler, the author of "*Indikator Versuche auf Pumpen*" and much other noted work, has, in conjunction with Professor Stumpf, produced single-action engines up to 2000 horse power, apparently of durable but expensive construction. I have drawings of these engines, accompanied by German text, with a list of engines in operation up to November of 1903.

There have been scores of abortive attempts in single-action machines, and no doubt there will be many more, because the problem, as a constructive one, offers a fertile field for the contriver incapable of understanding the impediments to be overcome.

The mechanical construction of machines should be approached by analysis of their operating conditions.

These latter are not amenable to computation, except a few, such as the strength of material, normal strains, endurance or wear and so on; but beyond these things lie what may be called the "phenomena of operation," that must be learned by observation, inference, analogy, and, for the most part, empirically.

To illustrate what I mean: The generation of electric current by dynamos was a well-founded science long before there were durable and reliable journal bearings for the armature spindles, and these are now a survival from endless modification. The commercial factors of symmetry, cost, endurance and many other qualities belong in the same category and are not computable.

It is not usual, in papers of this kind, to introduce the subject of constructing and operating machines, and it might be out of

place in papers relating to some kinds of machines employed in the arts; but, as before pointed out, information on this subject is, at this time, the lacking element in steam turbine practice.

At the risk of prolixity I will summarize, and restate in a compendious way the points already gone over, and then proceed to constructive features.

All fluid machines belong to two classes:

First, machines that receive and translate the force of fluids or motive engines of all kinds. Second, machines to impel fluids, including pumps of all kinds. This is a division easily understood. Fluids include air, steam, water, gas, all of which come under and are amenable to certain ascertained laws, and are divided into elastic and inelastic fluids.

Fluid motive engines are divisible into two classes—positive and free running. The positive class includes all that operate with pistons and which measure, positively and in proportion to movement, the amount of fluid that passes through them. There is no time factor in positive-acting machines; hence the rate of movement and the work done in a given time are under control. Within certain limits a positive-acting machine may run fast or slow, and its speed can be varied at will. The latter is the most important advantage that positive or piston machines have over the impulsive or non-positive type, and lends itself to a wide field of uses.

This advantage of a variable rate of movement is, however, diminishing all the time, because of the improvement in transmission gearing, designed to change the relative rate of movement.

The free-running class of fluid machines, those which operate by impulse and reaction, have a "time function" to deal with, and their speed is a determinate quantity, based upon the flowing velocity of the impelling or impelled fluid. This class embraces water wheels of all kinds—gravity, impulsive and reacting; also steam turbines.

The velocity of this impulse class of machines is inversely proportional to the density or weight of the fluids that impel them. A centrifugal pump and a rotary fan seem very different machines, but they operate according to the same law, and their speeds are inversely proportional to the weights of the fluids, or as 800 to 1. This indicates the great velocity at which single-action steam turbines must move, practically about 90,000 feet a minute.

Such a velocity produces various phenomena, such as the disturbance and stretching of the rotative parts by centrifugal strain; tendency to vibration, noise, the heating and wear of journal bearings and other things. The centrifugal strain can be imagined when we reflect that 1 pound of metal, on the periphery of a wheel

2 feet in diameter, will, at a speed of 10,000 revolutions per minute, represent a centrifugal force of 34,000 pounds or 17 tons.

Referring now to the constructive features of steam turbines, the first thing considered will be the buckets, and at the beginning I will claim that these are at fault in modern practice because of being curved in one plane only; consequently they have but one correct position in the jet throughout the whole arc of their movement and in nearly all cases are cut out of solid metal, and have angular or imperfect corners.

This form of buckets is due no doubt to the difficulty of machining their surfaces except in straight lines, but it produces, in turbine wheels, several features of construction that are far-reaching in effect, also far from apparent until carefully examined.

First. It increases the weight and number of buckets about fivefold in the attempt to secure impingement of the steam jets normal to the straight faces of the buckets.

Second. It distorts the course of reaction from a possible angle of 15° to an angle of 20 to 30° required to secure clearance.

Third. It makes necessary a side application of the jet, introducing lateral stress on the wheels and inducing vibration.

Fourth. It augments, in proportion to the added number of buckets, the amount of fluid friction.

Not to include the resistance of corners.

Fifth. The disposition of material in solid disks prevents the employment of its fibrous or laminated nature in the direction of strain and demands very expensive homogeneous material, a result indirectly of the numerous buckets.

This is a bold arraignment of certain constructive features, and would require great temerity on my part to bring forward were I not fortified by something stronger than inference and personal experience in this matter. I allude to the tangential water wheel practice on this Coast, which has passed through a crucial course of development that furnishes copious suggestion for single-action steam turbines.

The number of buckets is a very important matter. It is a sequence of the angle of impingement, and this again is a sequence of the bucket's shape, as will be shown further on. The surface or fluid friction, which offers a considerable resistance and loss, is in proportion to the number of buckets employed, and should be considered in this connection.

Most of the steam turbine buckets now made have angular corners, and, when there are not such corners, the end walls of the buckets are so distant from the jet as to lose reactive effect in that

direction. We long ago learned to keep water out of sharp corners in buckets.

In respect to the number of buckets or vanes, Fig. 5 shows how the line of impingement varies in respect to the straight faces of radial buckets, being as the sine of the angles A and B; and there is no way of securing impingement even approximately normal to the straight faces, except by employing a large number of buckets set close together. The result is much the same whether the jets be applied on the side or tangentially, as shown in Fig. 6, where the angle of entrance is 26° and that of discharge 36°.

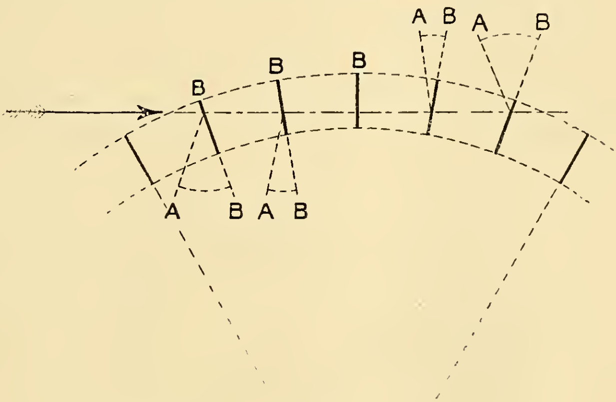


Fig. 5.

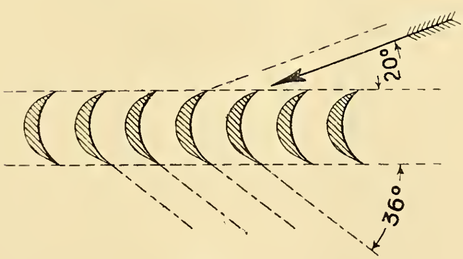


Fig. 6.

The trend of practice in tangential water wheels has been to wider spaces between the buckets, better angles for discharge, and, recently, to uniformly curved buckets, as hereinafter explained.

This feature of oblique impingement is accountable for at least three-fourths of the buckets now employed, and the result is loss by increased surface friction and distortion of the angle of reaction.

Fig. 6 shows approximately the entrance and discharge angles in the De Laval engines, embracing an arc of 56°, which, by reduc-

ing the number of buckets, could be reduced to 36° or less if the problem of oblique impingement were out of the way. Fig. 7 shows spacing for tangential buckets to secure an easy discharge at 20°.

In the Riedler turbines, the angle of discharge is 180°. In other words, the discharge is opposite the jet, but this calls for increased surface, more width and weight for the revolving member, and expensive work in construction, which are hardly offset by countervailing advantages, and which certainly prevent a cheap and general manufacture of the machines. It would not be becoming in myself to criticise the computations and designs of Professor

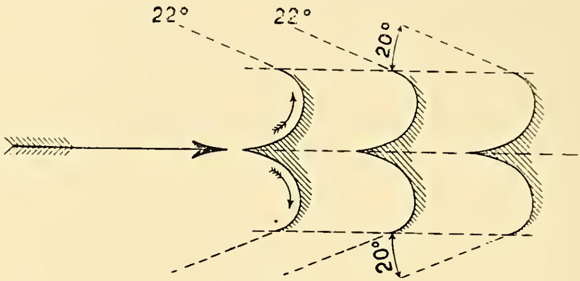


Fig. 7.

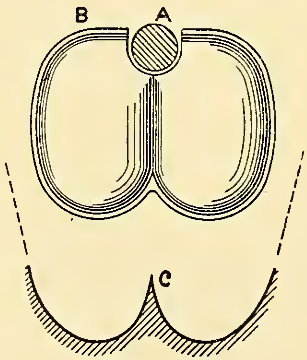


Fig. 8.

Riedler, but I am looking at the practical and mechanical phases of the problem, and seeking means whereby such engines may be made at a reasonable cost by common facilities and operate at reasonable efficiency.

The contention is that the buckets of steam turbines should be curved in all planes approximately as shown in Fig. 8, taken from a form of water buckets of a very advanced type by Mr. W. A. Doble of this city. These are of double concave or cup form, in order to permit direct and balanced impingement at the various angles in which they are presented to the jet, and have a central dividing

wedge to permit tangential application. This latter is not presented as a new idea, being simply the final form and method for tangential water wheels on this coast, after more than 25 years of continuous experiment and the attainment of an efficiency that is, if not final, so nearly so that a very narrow margin of avoidable losses remains.

If there exist any reasons why this same system or method of operating is not applicable to buckets for steam, I am not able to perceive it. Of course, expansion of the steam and divergence of the jets would call for modification not determinable until a form of nozzle and the contour of the jet are assumed.

Not knowing how far the contour of a jet of steam will permit its passage through notch A, in Fig. 8, I am not able to say how far this feature is applicable to an elastic fluid, or how far such a passage as that at A would become a spillway when a jet was impinging at the opposite end of the bucket. I will not discuss this here, further

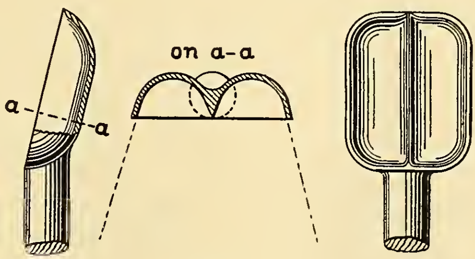


FIG. 9.

than to point out that this passage A avoids passing the rim B of the bucket through the jet and the disturbance that must result from this cause.

The dividing wedge C permits tangential application of the fluid and produces a shallow and balanced discharge. As a feature of impulse fluid motors, it has not met with analysis and adoption except on this coast and in the Riedler steam turbines. Its function, or rather its effect, is not always understood. The avoidance of side stress on wheels, especially on steam turbines at their enormous speed, is important, and so is the dual discharge which permits a more nearly uniform velocity throughout the discharged water section, because the latter is shallower. After many years of practical experiment, as well as some spent in scientific work, the dividing wedge was confirmed at the University of California in 1883* as a permanent feature of good practice for water.

In Fig. 9 is shown a form for buckets capable of receiving and

* Partial Turbines or Tangential Water Wheels. College of Mechanics, Berkeley, Cal. By Ross E. Browne.

properly reversing a jet of steam coming within angles A and B, and permitting the number of buckets to be reduced to what will come within and cover the divergence or expansion of the steam jet, or about 1 bucket for each 8° of arc for wheels from 20 to 40 inches diameter. This is less than one-fifth the number now employed for wheels having buckets straight in one plane, as in Fig. 6.

Such buckets can be stamped out of fine steel and made strong, smooth and integral with their radial supporting stems. They can be made of uniform thickness, with no more metal than their operative functions require, and of less than half the weight of those cut from solid metal, so that, compared with the usual form of steam turbines, there would be one-fifth the number and (excluding the fastenings) less than one-half the weight, so that the mass in the rim of a turbine wheel with this form of buckets can be reduced to one-eighth or even one-tenth of that in common practice.

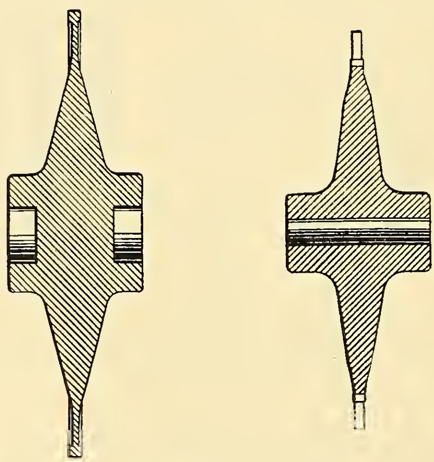


Fig. 10.

In the construction to be hereafter suggested, the buckets represent and constitute the whole rim of a wheel.

As to wheels or disks, nearly all now in use for single-action engines are solid disks, as shown in Fig. 10, a matter much to be wondered at if we consider the strains. Not everyone has had the opportunity of seeing disks at high revolution, circular saws, for example, which, at a speed of 10,000 feet per minute, assume a sinuous path at their peripheries and lose their stability by stretching.

A bucket, weighing an ounce, and revolving in a circle 24 inches in diameter at the rate of 10,000 revolutions per minute, will exert a centrifugal strain of 1 ton, and its supporting sector and

fastenings will exert 50 per cent. more—a result scarcely conceivable. The disposition of mass, strains and section may mathematically produce a body of the spindle form shown in Fig. 10 and in all diagrams that have been worked out by computation, but I do not believe that practical experiment will evolve anything of this kind.

Assuming this centrifugal force applied to a sector of a solid disk of uniform section, a circular-saw plate, for example, the error of such construction becomes apparent. The disposition of the material, in a sector of the wheel of which the bucket is the outer end, will be inverted, so to speak, and disposed inversely as the strain. The perimeter has no function requiring a continuous mass there, unless it be to hold a series of buckets set close together or to provide mechanical fastenings for them.

To compensate this contradictory disposition of material, the wheels are commonly made in lenticular form, as shown in Fig. 10, so that the mass of a sector is approximately a radial body of nearly equal section, apparently providing for centrifugal strain if change by elongation is ignored; but this latter is the principal fact of all, and one which cannot be provided for in a solid disk of any form, because the conditions are not ascertainable. I have made diagrams to show the mass, in 10° of arc, for several forms of wheels, but want of space prevents their reproduction here.

I have had made, by a very competent engineer, an analysis of the strains in several forms of solid disks, independent of elasticity and of change by stretching, a condition that defies computation in metal forms of the kind. It is an interesting and also an intricate problem, but I believe of but little practical value.

A very extensive analysis of such disks or wheels, made by Mr. Frank Foster, was published in *The Engineer*, London, No. 2506, January 8th of the present year. It is a study in mathematics of a very abstruse and no doubt interesting nature to students in calculus, but the weight and cost of such disks, if there were no other reasons, preclude their use for plain simple engines, such as those to which these remarks are directed. Professor Riedler seems to disregard such theories respecting the disposition of material in his disks.

I have shown how four-fifths or more of the weight in the periphery or rim of such wheels can be dispensed with, and I will suggest for the body of the wheels a construction which will eliminate inherent strains due to elongation or stretching, and at the same time dispense with the greater part of the mass and reduce the centrifugal strain accordingly.

In wheels moving at such high velocity, certainly the first thing

should be to remove from the disruptive zone all joints and mechanical fastenings. These must necessarily include an extra mass of inert material at the points of juncture, plus bolts, rivets or other means of attachment. Buckets or other parts fastened by dovetail joints are open to the same objection, because extra substance must be added to endure compression and holding strain.

The construction shown in Figs. 11 and 12 is suggested, the buckets being made independent, avoiding circumferential strain and permitting free elongation by centrifugal stress. The spokes B are tapered, so that their sections will stand the centrifugal strain within the mass lying outside of any point. They are fastened in a nave by welding or by suitable mechanical means, the strength of which will equal their section.

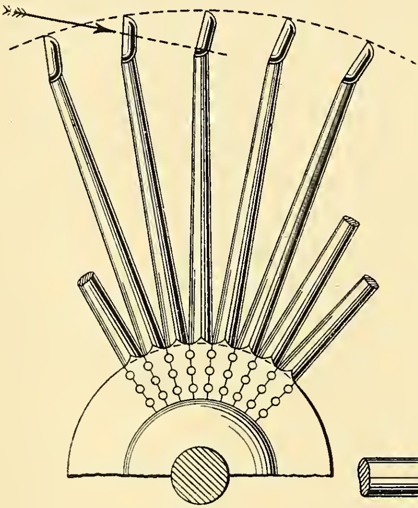


Fig. 11.

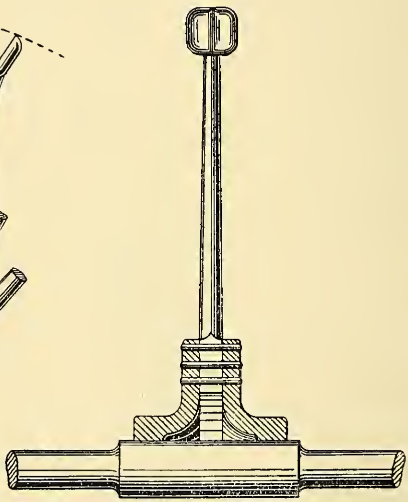


Fig. 12.

The nave of the form shown in the diagram will not expand and become loose on a spindle with the amount of weight in a wheel constructed as shown.

In respect to gearing for transmission, I believe that the principal impediment is a want of confidence. Nowhere in the arts have we been called upon for translation at such high velocity; consequently we are not prepared to provide devices such as are required to reduce the speed of single-action steam turbines, where the elements of transmission have to move from 4000 to 6000 feet per minute. I know of no reason why plain tooth wheels, or tangent gearing, will not run at this speed, and I confidently expect that they will do so without any objectionable result.

Respecting tooth gearing there is much apprehension, which arises from the difficulties of constructing it in perfect form. In the Continental Hotel in Philadelphia a screw elevator was in use for more than twenty years. A bevel wheel of 5 feet diameter and a pinion of 10 inches diameter drove the screw, and they were absolutely noiseless. They were made at the Industrial Works in that city, where I was working at that time.

In an experiment made many years ago, at the works of William Sellers & Co., to test the ultimate speed of transmitting apparatus, bands of one kind or another were employed up to a point of failure, then plain spur wheels were resorted to, and, as I have been informed, they were entirely successful to the point of disrupting a steel disk driven by the gearing. Of course, such gearing to run without noise must be perfectly made; and, if there is reason why they will not transmit at 4000 to 6000 feet per minute, I fail to conceive it, especially when inclosed in the turbine wheel chamber, as hereafter suggested.

Twenty-five years ago I constructed machines in which bands of flax webbing ran at 6000 feet per minute without difficulty.

These bands drove spindles at 12,000 feet per minute, and the machines are yet in use in Columbus, Ohio, where they were made in what might be called a country shop.

For a good many years I was engaged in designing and making machines in which the spindle bearings had a velocity of from 2000 to 3000 feet per minute, were subject to lateral strain and mounted in weak framing, and they ran cool when the fit and alignment were good. Consequently I am in no way alarmed at the requirements in steam turbine practice, and I confidently expect to see power transmitted by bearings moving at a surface velocity of 5000 feet per minute and spindles run cool at 10,000 to 15,000 revolutions per minute.

In my opinion, the gearing of transmission should be inclosed with the motor wheel, and should operate in the vapor contained in the casing, that being open to a condenser. There are three reasons for this: (1) The better performance and wear of wheels when steam lubricated; (2) the absorption of noise, if that be present; and (3) the avoidance of packing glands on the spindle of the motor wheel, a very objectionable feature, present, I believe, in all the steam turbines now made.

Such packing glands are objectionable not only because of a possible resistance and loss of power by friction, as pointed out by Professor Sweet, but because they permit the entrance of air into the condenser and involve the wear and care of packing.

The interior of the wheel casing should be annular, turned smooth and otherwise so arranged as to permit the free revolution of any vapor it may contain. It has been suggested that a sector or spoke construction of the wheels would cause serious resistance by windage or fanning the steam or vapor in the casing; but the attenuated vapor in a casing, 10 to 12 pounds below the atmosphere, would not offer much resistance if fixed, and perhaps none to consider at all, if free to revolve with the wheel.

In respect to bearings for the wheel spindle, these should be parallel, hardened and ground, mounted in pivoted split shells of cast iron, and, like the reducing gearing, inclosed in and exposed to the vapor of the wheel chamber. This may seem objectionable because of heat, and it would be so in machines as now arranged, with the casing exposed to a high temperature.

This latter I believe to be a mistake. No avoidable heat should be communicated to the casing to raise its temperature above that of the expanded steam. A low temperature would not cause appreciable thermal loss in the jet, but would assist a condenser and conduce to other desirable objects that have been named.

In respect to nozzles for buckets, such as have been suggested, it is a difficult subject without experiment and when the contour of a jet at different pressures is not known. I am of the opinion, however, that if inclosed the tube should conform to the natural contour of the jet. With side application of the steam on buckets flat or straight in one plane, there is no doubt a gain results from the use of a diverging nozzle, but in buckets in which the jet is divided the case is different.

On the whole, I think it safe to assume that the form of nozzles for steam turbines of the single-acting type is not a problem that will much interfere with their successful construction. That there should be a converging anterior chamber, a throat to determine volume and a diverging nozzle is obvious, but further than this the result is no doubt a refinement that has more importance in a mathematical theorem than in the workshop.

Some years ago, I think in 1901, I asked Mr. Brown, whom I have several times quoted, his opinion respecting steam-motor nozzles. He replied as follows:

> As regards the De Laval nozzles, the learned here are of various opinions as to their value. Professor Meyer, in Zurich, who has experimented long with the De Laval, says that it is in no way superior to a common nozzle.

The views and suggestions which I have had the privilege of advancing here have been imperfectly embodied in an organized mechanism, shown in Fig. 13. This drawing was made about two

years ago, and it would be modified in various ways if reproduced now. It, however, embodies most of the features that have been suggested.

I presume this presentation of a subject, without the scientific furtherance common at this day, can hardly be considered a conventional contribution to the art. It may not be so accepted, but I venture the prediction that the evolution of cheap steam turbines, adapted for general manufacture and use, will before long result from effort and experiment on the part of intelligent and experienced mechanics aided by scientific data.

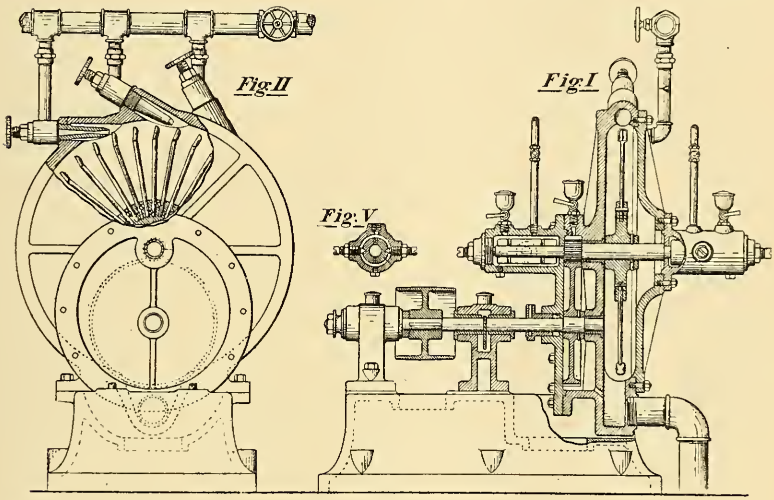


FIG. 13.

This assumption has some answer in the fact that, already mentioned, 75 years ago Mr. Avery, a country millwright in Western New York, made successful reaction steam turbines, and applied a large number of them successfully to common rough uses. He also made impelling members which contained about one-tenth of the material now employed, and, as I believe, in a more practical manner than in many wheels now being produced. The work was done in blacksmith shops, at a time when accurate tools and processes were almost unknown, and I am much inclined to agree with the opinions of Prof. John E. Sweet, whose skill and judgment no one is likely to question, who, in a recent letter to the author, said: "If I were to engage in the manufacture of steam turbines I would begin with the Avery one."

The steam turbine practice of our day is the finest example of constructive engineering work that the world has ever seen. It is

confined to large units, not because of operative impediments in small engines, but because these cannot be furnished separately at such prices as can be obtained.

From these premises I conclude that future steam turbines for common use will be single acting and condensing whenever possible, with wheels of sector construction as light as can be made. There will be no packing glands on the main spindles, and the first movers for transmission will be plain spur or tangent gearing.

I will conclude this paper with brief mention of the economic results that have been reached with steam turbines, as illustrated by the generating engines recently constructed in Switzerland, one with very high-class piston engines and one with turbines, each of 5000 horse power. The results were as follows:

Weight of piston engines and generators, 598 tons. That of the turbines and generator only 78 tons, or nearly 8 to 1. The steam consumption by the piston engines was 11 pounds per indicated horse power, and for the turbines 1 kilowatt with 14 pounds of steam, or about 10 pounds per horse power. Oil consumption was as 20 to 1 in favor of the turbine, and attendance about 5 to 1.

The piston engines were made by Messrs. Sulzer Bros., of Winterthur, and the turbines by Messrs. Brown, Bouveri & Co., of Baden, in Switzerland. The quantities were furnished to me by Mr. Brown, of Basel, Switzerland, with whom I had personally discussed the subject some time before the tests were made and who had forecast the result with much accuracy.

THE RECLAMATION OF A MOUNTAIN SWAMP.

By Marsden Manson, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 27, 1904.]

[Note.—The execution of this work has been very actively and ably carried out by Mr. Ralph E. Parker. He has made all surveys, and has laid out and constructed the main canal and irrigation ditches and the temporary and movable dams. The writer is indebted to him for the data concerning construction and cost.]

The features with which this paper deals lie in Harney County, Southeastern Oregon, and in the broken and upheaved southern portion of the Columbia Lava Plain. This lava plain has been elsewhere described by the writer (*American Geologist,* Vol. XXIV, 1899, pages 203-209). It covers large areas in Washington, Oregon, California, Wyoming, Idaho and Nevada, and dominates the physical geography and topography of over 150,000 square miles in these States.

The drainage areas and swamp with which we have to deal cover about 450 square miles of a block of lava some 1000 square miles in area, and from 1 to 1¼ miles thick. This broken, tilted and distorted block lies between 2 nearly parallel faults some 25 miles apart and over 40 miles long. The upthrust along the easterly fault is apparently 1 mile or 1¼ miles, and constitutes the bold feature known as Stein Mountain, which reaches an elevation of 11,000 feet above sea level. The easterly slope of this mountain shows a broken and precipitous front, rising above the general level about 1 mile or 1¼ miles, and showing that the lava has approximately this thickness. The westerly slope is a gentle descent of about 5°, partly dissected by rifts and gorges in the lava, and terminating in low bluffs of basaltic lava bordering the easterly side of Blitzen Swamp and rising a few hundred feet above its level. On the westerly border of this swamp and marking the position of the westerly fault plane is another bold escarpment, locally known as "Jackass Rim Rocks," where the vertical movement has probably been 800 to 1000 feet.

Donner and Blitzen Rivers and several minor streams drain about 400 square miles of the west slope of Stein Mountain. In their upper reaches they occupy deep gorges, in which snow drifts and packs in the winter. Snow also accumulates in the thickets of dwarf aspen which grow wherever the soil is deep enough to give roothold. The precipitation upon this drainage area amounts to about 15 inches per year, mostly in the form of snow. Rapid melting in the spring and early summer causes the floods which reach

Blitzen Swamp. Low-water discharge is furnished by springs in the gulches. Accurate hydrometric data were not available, and as the projected reclamation contemplated the use of the swamp lands for raising hardy forage grasses for hay and pasture, short periods of flooding could do no harm. The features above mentioned are given an outline expression in the accompanying sketch map and general sections.

BLITZEN SWAMP.

Blitzen Swamp thus lies in the valley depressed between these 2 basaltic rim rocks, and extends into the lower ends of their lateral gorges. The total area is about 50 square miles, having a length of 22 miles and a mean width of 2.5 miles, and an elevation of about 4500 feet above sea level. The entire valley is about 32 miles long. The swamp is naturally divided into 4 sections—*the Upper Swamp, the Gorge, the Lower Swamp* and *Diamond Swamp,* the latter being an extension into a gorge on the easterly rim rock or lava escarpment.

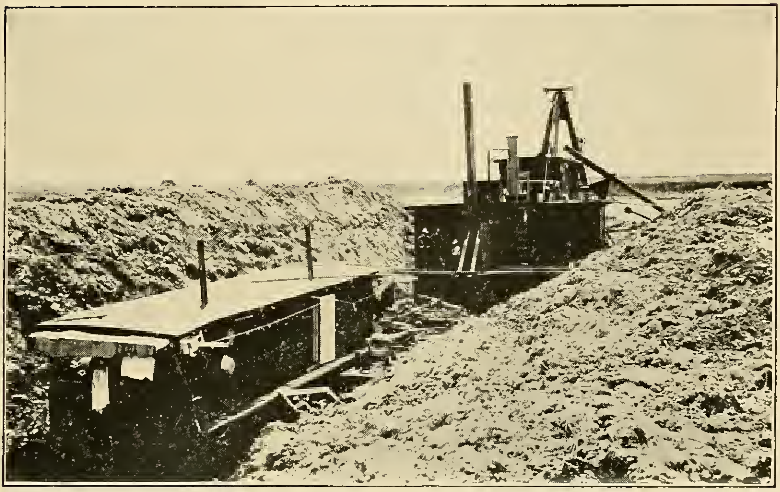
The fall through this valley is not regular, and in the aggregate amounts to 95 feet, 35 feet of this fall being in the upper 7 miles, 25.8 feet in the canalized portion and the remainder in the river to Malheur Lake. The surface of the valley presents all stages of the process of development: (1) Cones of cobble and gravel merging into alluvial lands overgrown with brush. (2) Tule, flag and canebrake swamps, with peat soil resting on a peaty, loam or clay subsoil. (3) Floating islands or "blankets" of peat, on which tules, flags and aquatic plants flourish. (4) Ponds and lakes deeper than the level of proposed drainage. Irregular channels meander through the entire area. In some instances these channels were concealed beneath floating blankets of peat. These blankets were cut up with hay knives and dragged ashore.

The upper portion of the upper swamp has received sufficient sediment to give it steeper gradients, and has been partially cleared and drained and converted into very valuable hay and meadow lands, which are well irrigated. It is not proposed to extend the canal into these lands, as the natural channels have already been improved by scraping them out and by rough rectifications. The main canal will intercept these channels about the middle of the upper swamp. The remainder of the swamp is principally a vast tule swamp, with peat soil and a peaty or clay subsoil.

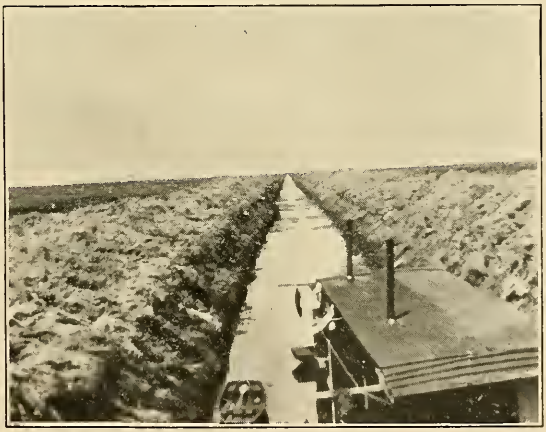
These features are made clearer by the accompanying map, sections and illustrations.

At the lower end of the swamp the basaltic blocks or rim rocks

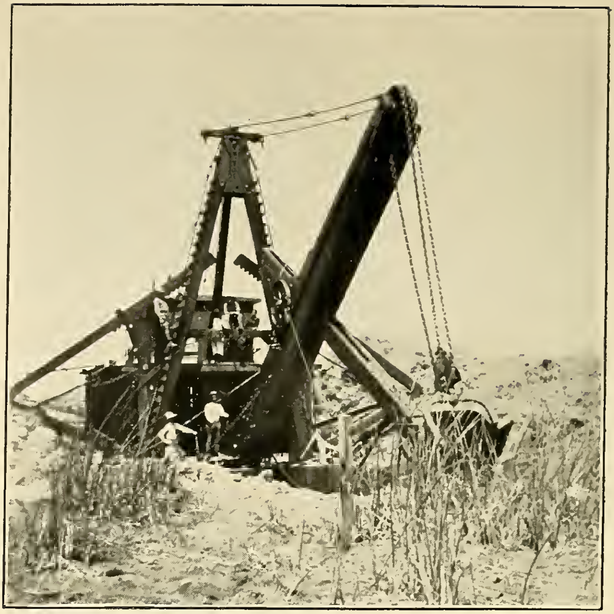
Busse Irrigation Ditch under Construction.



Dredger "Blitzen" and Ark.



Main Canal, Looking Down from Dredger.



Front View of Dredger, Middle Swamp.

Middle Swamp.

fall back and inclose low, flat benches of arid land covered with sagebrush, and aggregating some 15 or more square miles. Over about 12 square miles of this land it is possible to divert water for irrigation.

The writer was called upon to advise as to the possibilities of drainage, the size and location of canals, the type and power of machinery to use and the possible diversion of the drainage waters for irrigation. The problem presented interesting and important features:

First. The drainage of an elevated swamp of considerable area and restricted outfall.

Second. The control of this drainage so as to give broad or subsurface irrigation over the drained area.

Third. The use of the drained-off waters for the irrigation of arid land. This feature was of high importance, by reason of the partial reclamation of the lands bordering Malheur Lake, at the outfall of the Blitzen Swamp. The natural disposition of the spring and early summer floods was principally by evaporation from the 50 square miles of swamp surface.

After an examination of the field of operations and of all data available the summary of the report to the owners was that:

(1) The drainage of the greater portion of the swamp was practicable with a well-aligned main drainage canal having the general fall of the swamp and a sectional area of 260 square feet, but that for short periods of excessive flood partial submergence would occur; that such auxiliary canals as might be found necessary might be considered after the construction of the main canal.

(2) That the waters drained from the swamp should so far as possible be used for the irrigation of the arid lands bordering the lower swamp.

(3) That the best type of dredger to be used was a dipper dredge, with a bucket $1\frac{1}{4}$ cubic yards capacity and a delivery 45 to 50 feet from the center of the canal, the following details of machinery, etc.: Fifty horse-power boiler, locomotive type, 44 inches x 11 feet, large firebox and doors (woodburner). Two engines, 10 inches x 12 inches, for operating crane, 7 small auxiliary engines for hoisting spuds, etc.

Maximum weights were as follows: Crane 8 tons in 3 parts, $2\frac{2}{3}$ tons each.

Boiler, naked, 7000 pounds. Other parts easily handled. (These parts had to be hauled about 200 miles.)

The hull was designed to be 24 feet x 75 feet x 6 feet, but was reduced to 19 feet x 75 feet x 6 feet. As lumber had to be hauled

60 miles from the Blue Mountain Mills, detailed bills of lumber were made out, and equal care and economy were necessary in all ironwork.

The estimated capacity of this plant was as follows:

Under ordinary conditions, 30 linear yards per day of channel, 3 yards deep, 8 yards wide slopes $\frac{1}{1}$, or about $\frac{1}{3}$ mile per month.

Under favorable conditions, 55 linear yards per day, or nearly $\frac{2}{3}$ mile per month, or the entire 13.2 miles of canal in 24 months' work.

It was recommended that where the conditions permitted, that the swamp be cross-sectioned 1000 feet apart, and the canal line located along the lowest ground and most direct alignment, and the ground sounded particularly in the "Narrows," to avoid possible cutting into submerged masses of lava.

The cost of machinery and hull was estimated at $9750, to which was added freight to Winnemucca, hauling to the site an ark or quarter boat and 2 wood scows, costing $8200, as follows:

Freight from Marion. Ohio	$2,100.00
Hauling from Wimnemucca	1,200.00
Cost of ark, wood scows, etc.	4,900.00
	$8,200.00
Estimated cost of machinery and hull, as above	9,750.00
Bringing cost of outfit to	$17,950.00

The ark and wood scows are 9 feet x 36 feet x 2 feet.

Force required:

One engineer, 1 fireman, 2 deck hands and 1 cook.

Together with such woodchoppers, teams and drivers as might be found necessary to supply fuel.

Fuel, 2 to 3 cords of wood per day, according to quality—sagebrush could be used.

The surveys were conducted by Mr. Parker, mostly in the winter, when the swamp was frozen over. The tules, flags, etc., are frequently 12 to 14 feet high, so that a mowing machine or drags drawn by horses were used to clear the lines. The surveys occupied 200 days, and cost about $1700, and were completed in the spring of 1902.

The dredger hull and barges were about $2\frac{1}{2}$ months in constructing, and were completed and ready to operate by the middle of April, 1902, and cost practically as estimated.

During the spring and summer of 1902 a little over a month's dredging was done, when the operations were stopped by low water and to complete surveys. Work was resumed in November, 1902, and has progressed regularly to date, with the exception of about 5 months of severe freezing weather.

The canal has been constructed from the lower end of the swamp to the upper part of the gorge, a distance of 7.6 miles.

RESULTS, COST, ETC.

These are best measured by the work of 1903. During that year the total working time was 199½ days of 10 hours.

Canal excavated 24,700 feet, or 222,000 cubic yards. Average per day 123.8 feet, or 1100 cubic yards; average per month of 26 days 0.6 mile.

Wood burned, 500 cords	$2,350.00
Labor	2,800.00
Board of employees	800.00
Oil and waste	150.00
Repairs and replacing worn parts	500.00
Total	$6,600.00

Or 27 cents per linear foot of canal; 3 cents per cubic yard.

Charging up one-quarter of the cost of the plant as a sinking fund to one-half of the work, the cost has beeen 4.12 cents per cubic yard. A clam-shell dredge might have given slightly better results in much of this work, but a portion of the bottom material is too hard to be economically handled by this type of machine, which fact ruled in the selection of the dipper dredge.

Fuel in the form of sagebrush or of dwarf juniper was available. The cost of delivery was about the same, but the labor of firing greater in the case of sagebrush—2 cords being about equivalent to 1 of juniper. Juniper wood was hauled 6 to 7 miles and sometimes rehandled; it cost from $4.70 to $3.10 per cord, and has an efficiency greater than pine. The consumption has been at the rate of about 2½ cords per day, or 108 cords per mile of canal; in the peaty subsoil this consumption drops to 70 or 80 cords.

SUMMARY OF RESULTS.

Over ½ or 7.6 miles of canal are completed—25 square miles of the swamp have been drained; 15 square miles of this area are in use, and can be flooded by the use of movable dams in the canal.

The Busse irrigating ditch has been constructed for 10 miles and nearly 6 square miles of arid land brought under irrigation.

The remainder of the canal, about 5.6 miles in length, is being constructed at the rate of over ½ mile per month; and, unless unexpected interruptions occur, will be completed in 12 working months. The West Side irrigation canal will have to be constructed during this period. It will bring under irrigation 6 square miles more of arid sagebrush land.

The necessity of this use of the drained-off water for irrigation has been previously pointed out; a brief recital of the conditions and work done under this requirement will now be made.

The ultimate drainage of the swamp reaches Malheur Lake; around its edges and upon the lower reaches of the river there are reclaimed lands. But, as previously mentioned, the greater portion of the discharge of Blitzen River was naturally taken up by evaporation from the 50 square miles of swamp surface. To drain this quickly down upon pasture and hay lands would provoke suits for damages; hence the irrigation of the sagebrush lands bordering the lower swamp became not only advisable, but obligatory.

The area over which irrigation can be readily extended is about 12 square miles. Nearly one-half of this has been brought under irrigation by the Busse Ditch, on the easterly side of the Blitzen Swamp. This ditch is 10 miles long, and was constructed with plows and drag scrapers. The various sections of a mile each were proportioned to the area to be served by each, as follows:

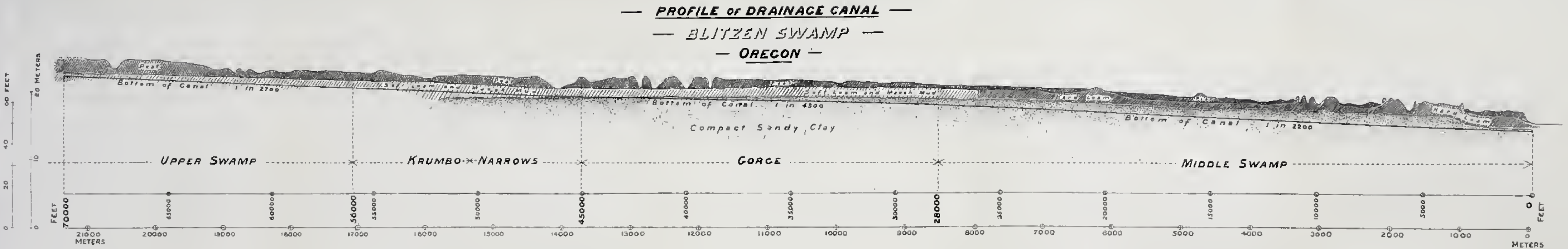
	Capacity Sec. Ft.	Width at Bottom, Feet.	Depth of Water, Feet.	Grade, Ft. per Mile.	Area to be Served, Rate of 1 Sec. Ft. per 50 Acres.
1	73.5	25.0	3.25	0.75	3,676
2	72.1	25.0	3.0	0.75	3,607
3	68.9	25.0	3.0	0.75	3,446
4	63.8	22.0	3.0	0.75	3,190
5	60.0	20.0	3.0	0.75	3,002
6	48.5	17.0	2.8	1.00	2,424
7	37.9	12.8	2.5	2.00	1,897
8	20.6	6.0	2.0	2.50	1,029
9	7.1	3.0	1.5	3.50	355
10	1.2	ditch constructed with a plow		4.25	62

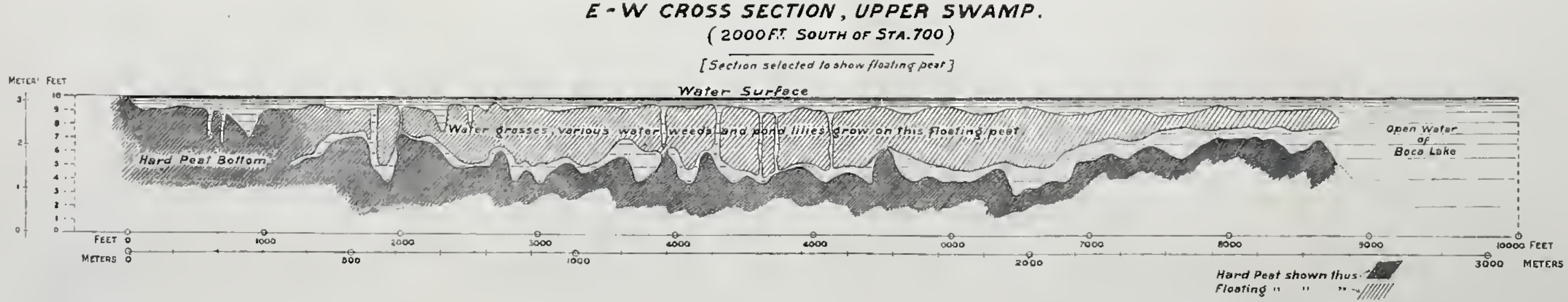
The general character and mode of constructing this ditch are shown in the illustration.

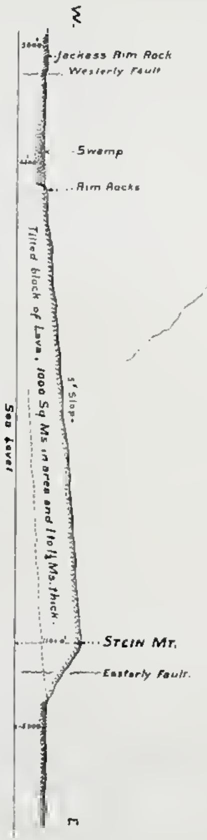
The satisfactory results obtained in this work are largely due to the fact that the work was a unit, entirely in the hands of the engineers. The work was carried out according to a general plan, without the intervention of boards of trustees and self-constituted critics and advisors, and without regard to its political effect. If the far grander problems in the lower reaches of the Sacramento and San Joaquin Rivers and elsewhere could be attacked under the same conditions, equally good results could be obtained.

NOTE.—Since the above was written Mr. Parker reports for May:

Days under steam	27	
Days run	26½	
Total distance dredged	6,000	feet.
Dredged per day's run	226	"
Total wood burnt	75	cords.
Wood burnt per day under steam	2.8	"
Wood burnt per 100 feet dredged	1¼	"
Cubic yards moved	41,000	


— PROFILE OF DRAINAGE CANAL —
— BLITZEN SWAMP —
— OREGON —
Peat
Bottom of Canal 1 in 2700
Bottom of Canal 1 in 4500
Compact Sandy Clay
Bottom of Canal 1 in 2200
UPPER SWAMP
KRUMBO NARROWS
GORGE
MIDDLE SWAMP
FEET
METERS
21000 METERS
0 METERS
70000
56000
45000
28000
0 FEET


E-W CROSS SECTION, UPPER SWAMP.
(2000 FT. SOUTH OF STA. 700)
[Section selected to show floating peat]
Water Surface
Water grasses, various water weeds and pond lilies grow on this floating peat
Hard Peat Bottom
Open Water of Boca Lake
FEET
METERS
10000 FEET
3000 METERS
Hard Peat shown thus
Floating " " "



General Section Showing Formation of Blitzen Swamp & Stein Mt.

— BLITZEN SWAMPS —

Sketch Map

of Reclamation and Irrigation Scheme.

Labor and Expenses.

Crew, including cook, etc.	$380.00
Repairs	10.00
Lubricants	25.00
Hauling wood	200.00
Cutting "	113.00
Total	$823.00

Or about 2 cents per cubic yard.

In reply to an inquiry by Mr. Molera, the author would say that the dredger attacked clay, sand and packed gravel with considerable ease. Those strata are shown in the profile that accompanies the work, and the bottom of the canal in places goes down into compact sandy clay, which is not quite so hard as our hard pan, though if the dredger could once get a start under the edge of hard pan it would easily attack it; and that was one of the main conditions that ruled in the selection of a dipper dredge. The clam shell would not economically attack the harder class of material here dealt with.

PIPES AND JOINTS FOR HIGH PRESSURES.

By Franklin Riffle, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 27, 1904.*]

The tendency of the times is to use higher pressures for the transmission of water, steam and gas, thereby reducing unit costs. On the Pacific Coast conditions are exceptionally favorable for utilizing water under high heads, in order to manufacture comparatively cheap power. During the last ten years California engineers have had the good fortune to design and construct a number of high-pressure plants, and incidentally to contribute much valuable experimental knowledge to the science of hydraulic engineering.

The subject is of vital concern to the engineer, for upon him devolves the responsibility of selecting, with intelligent discrimination, the class of pipe and design of joint that are best adapted to meet the conditions confronting him—having due regard for stability on the one hand and economy on the other. To combine properly these two functions often calls for the exercise of engineering knowledge and skill of the highest order.

The object of this paper is to discuss, as concisely as possible, the several types of pipes and joints that have recently been used for high pressures, with special reference to Pacific Coast practice.

PIPES.

On account of its high tensile strength, combined with other favorable physical properties, such as elasticity, malleability and ductility, steel is peculiarly adapted to withstand the stresses to which pipes are subjected when under pressure. Steel pipe, therefore, has been almost universally adopted for high-pressure work. While many engineers prefer cast-iron pipe for low pressures, on account of its extreme thickness and consequent long life, it is manifestly not adapted to higher pressures. No amount of care in the manufacture, inspection and testing can be relied upon to prevent pipes that are inherently defective from being accepted and used. Such pipes have been known to pass a rigid inspection, including a high hydrostatic test, only to crack in the most mysterious manner when subjected to a low working pressure. This is why steam engineers have discarded cast-iron pipe, and why hydraulic engineers, when dealing with pressures in excess of those ordinarily used in munici-

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pal water distribution, are inclined to use it with extreme caution. A notable instance of the use of cast-iron pipe for high pressures is in connection with the Colgate plant of the California Gas and Electric Corporation, where the maximum static pressure for 30-inch pipe is 305 pounds per square inch. In view of the general distrust, by hydraulic engineers, of this class of pipe for high pressures, it would be interesting to know to what extent the Colgate experiment has been successful.

STEEL PIPE MAY BE EITHER RIVETED OR LAP-WELDED.

Riveted pipe is distinctively a California type, having been introduced into the State many years ago, when sheets of iron in stock sizes were brought from the East by sailing vessel to San Francisco, where they were cut to various sizes, punched, rolled and nested. In this compact shape sheets of the proper sizes were transported by water, wagon road and trail to the various mining camps in the interior, where they were riveted together. Even after the advent of railroads riveted pipe continued to be used in California, almost to the exclusion of other types, chiefly on account of its relatively low cost. Increased transportation facilities, however, made it possible to have the pipe riveted into long sections in the well-equipped pipe shops of San Francisco, Los Angeles and Sacramento, a practice which prevails at the present time.

Riveted pipe is made into convenient lengths for handling (20 to 30 feet) by riveting together either conical sections or alternately large and small cylindrical sections, 3 to 6 feet long, each of which has a double-riveted longitudinal seam. The double rows of holes for the longitudinal seams and the single rows for the round seams are punched by power machines, and all overlapping edges are bevel-sheared. After the plates are rolled into cylindrical form and riveted, the seams are made tight by means of a pneumatic calking hammer operating against the beveled edges.

Butt joints with either 1 or 2 cover plates (the latter being presumably the stronger) are sometimes used for shells over $\frac{5}{8}$ inch in thickness. Outside cover plates are bevel-sheared and calked on both edges.

The efficiency of riveted joints may vary from 40 per cent. to 65 per cent. for single riveting, and from 55 per cent. to 75 per cent. for double riveting. As the strength of riveted pipe depends upon the shearing resistance of the rivets and the plates, and this, to a very large extent, upon the thoroughness with which the riveting is performed, it is apparent that rigid inspection during the progress

of the work is essential, in order that the highest efficiency may be obtained.

In the manufacture of lap-welded pipe the longitudinal edges of each plate are scarfed, the plate is rolled in bending rolls until one edge overlaps the other, after which the skelp (as it is termed in mill parlance) is heated to the welding point in a welding furnace and then drawn over a mandrel and through a pair of rolls, the pressure of which on the lapping edges welds them firmly together. The welded joint has a much higher efficiency than the riveted joint, and presents the additional advantage of being as smooth as any other portion of the shell. Moreover, lap-welded pipe has no seams corresponding to the circumferential seams of riveted pipe.

Because of its superior welding properties, soft or mild steel is used by pipe manufacturers in preference to high-carbon steel. For screw-joint pipe Bessemer steel is preferred to open-hearth steel, owing to the difficulty of cutting perfect threads when the latter is used. When the ends of the pipe are to be flanged, open-hearth steel is preferred. When neither threading nor flanging is required, steel made by either process will answer equally well.

In high-pressure pipe lines used for water-power development it has been largely the practice in California to use riveted pipe at the upper end of the line, where the pressures are not excessive, and lap-welded pipe at the lower end. Riveted pipe can be made of lighter plates than lap-welded pipe, which requires a minimum thickness of metal (varying with the diameter of pipe), below which the skelp will not retain its cylindrical form when exposed to the heat of the welding furnace. To illustrate: For 24-inch lap-welded pipe the minimum thickness of skelp that can be used is $\frac{5}{16}$ inch, and for 26-inch pipe, $\frac{3}{8}$ inch, although the pressure conditions may be such that $\frac{3}{16}$-inch shell will be amply strong. In the interest of economy, therefore, it may be found advisable in this instance to use riveted pipe; but when the computed thickness of shell is equal to or greater than the minimum thickness for lap-welded pipe, there is rarely anything to be gained by using pipe with riveted seams.

Up to the present time 30 inches (outside diameter) has been the largest lap-welded pipe made, and that only by one mill—the McKeesport Mill of the National Tube Company. But as preparations are now being made to manufacture 36-inch pipe, this size may be considered the maximum for lap-welded pipe. Therefore, whenever the desired volume of water is too large to be conveyed by a 36-inch pipe, it may be necessary to choose between 2 lines of lap-welded pipe and a single line of riveted pipe. The latter plan

is evidently the more economical, although if the pressures are excessive there may be no alternative but to adopt the former, or at best a combination of the two. Thus it is obvious that each class of pipe has its advantages and also its limitations; and while there can be no question concerning the superiority of lap-welded pipe, the element of cost often operates to restrict its use to the highest pressures.

JOINTS.

Lead joints have been employed with excellent results in pipe lines of small diameters conveying water under fairly high pressures. The bell and spigot type of joint has been used under a variety of modified forms for connecting lap-welded pipes, but only two have survived the test of many years of experience. These are the Converse and the Matheson joints.

The *Converse* lock-joint, or coupling, Fig. 1, consists of a heavy cast-iron hub, with internal recesses at each end, which receive two lugs or rivets fastened to each end of each length of pipe. After the pipe enters the hub it is revolved slightly until the joint is "locked."

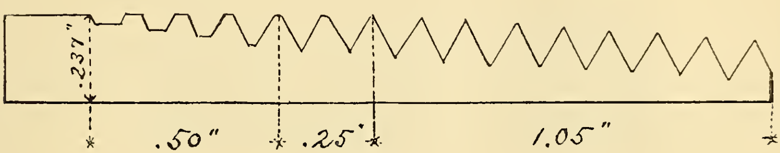


FIG. 1.

In this position it is impossible to pull the pipe out of the hub without first shearing off the rivets. The annular space between the pipe and the hub is then poured with lead and calked in the usual way.

The *Matheson* joint is formed by expanding one end of each length of pipe sufficiently to form a bell or socket, which is reinforced at the extreme end by shrinking on a steel band. A groove is cut around the outside of the spigot end, to resist the tendency of the lead packing to slip when the joint is under pressure.

Of the two forms of lead joint described the Converse is much the stronger, and therefore better adapted to high pressures. When reasonable care and skill are used in laying Converse pipe, the joints can be relied upon to stand much higher pressures than are commonly considered safe for lead joints. In the summer of 1901 a pipe line was laid by the Pacific Improvement Company near Santa Barbara, consisting of 10,000 feet 7-inch No. 9 gauge, 10,000 feet 8-inch No. 8 gauge and 13,500 feet 8-inch No. 6 gauge, all Con-

verse joint steel pipe. This line terminates in two branch lines, each leading to a reservoir. At the end of each branch is a gate valve. As the total head is 1370 feet, it was not intended that both gates should ever be closed at the same time. However, after the line had been in operation for some time, an employe carelessly closed one of the gates without first opening the other, with the result that the entire line was subjected to a static pressure that amounted at the lower end to 590 pounds per square inch. A careful inspection of the line soon after failed to disclose a single leak. Another example, the 8-inch force main of the Prescott (Arizona) Waterworks, where several miles of Converse steel pipe 0.14 inch thick are being operated under a maximum working pressure of 420 pounds per square inch, is a forcible illustration of the efficiency of a properly designed and well-made lead joint, even for high pressures.

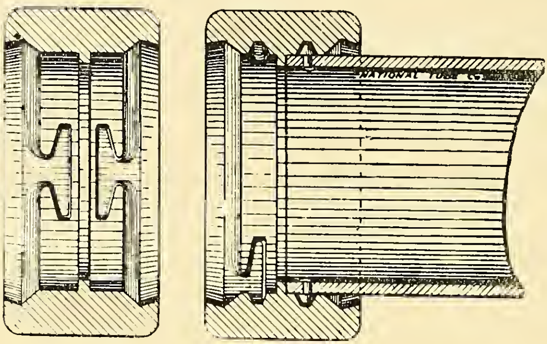


FIG. 2.

These examples have been cited to show that although lead joints for high pressures are not generally regarded with favor by hydraulic engineers, they are nevertheless worthy of some consideration. They have the merit of being economical in first cost and of being easily and readily repaired in case of leakage. Generally speaking, however, the working limit for lead joints should not exceed 300 pounds pressure per square inch.

Screw joints are formed by means of sockets or couplings, into which are screwed the threaded ends of the pipes. Couplings for standard pipe have straight threads, while the pipe threads have a taper of $\frac{3}{8}$ inch to 1 foot. After screwing together a number of standard pipes, it will be found that at nearly every joint a portion of each pipe thread remains exposed outside the socket. These are the weak portions of the pipe, and there is always danger of breakage at the bottom of an exposed thread from bending stresses which cannot always be avoided in laying a line of pipe. This danger,

however, is minimized by the practice of cutting vanishing threads on the pipe. Fig. 2 shows a section through the threaded end of a 4-inch standard pipe. The threads have a pitch of $\frac{1}{8}$ inch (8 threads per inch), and their total length is $1\frac{8}{10}$ inches. Starting at the end of the pipe there are 8 perfect V-threads, then 2 threads that are perfect at the bottom and slightly flattened on top, and finally 4 imperfect threads, the last one being but little more than a scratch.

The *line* pipe coupling (Fig. 3) is a modified form of the standard pipe coupling, from which it differs in the following important details:

1. It is longer and heavier.

2. The ends are recessed, in order that they may fit the pipe snugly just outside the thread, which is thereby fully protected from any bending stresses that may come upon the pipe.

3. The threads have a taper of $\frac{3}{4}$ inch to 1 foot, to correspond to the taper of the thread of the pipe. This insures a perfect contact for every thread—a prime essential for tight joints.

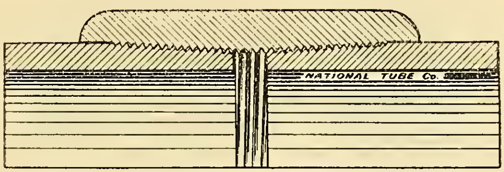


FIG. 3.

A leaky line pipe joint indicates imperfect or damaged threads or carelessness in connecting the pipes. To avoid damage from transportation, it is the practice of the best mills to screw a heavy guard or protector (usually a half coupling) on the exposed thread of each length of pipe.

In California, line pipe is largely used to convey oil under pressure. A considerable number of 2-inch, 3-inch and 4-inch lines are in operation in the several oil fields of the State, and some of them are subjected to very high working pressures. (The Standard Oil Company's 8-inch line will be referred to later.)

Line pipe is also used in California for the transmission of gas under high pressures. In many localities it is more economical to supply two or more towns from one source, through small pipes at high pressures, than to construct and operate a generating plant in each town.

In one of the first attempts at high-pressure gas transmission in this State 2-inch standard pipe was used, but after the completion of the line the joints leaked so badly at a pressure of 15 pounds

per square inch that it became necessary to take up the pipe and relay it after replacing the couplings with line pipe couplings. In contrast with this unfortunate experience may be mentioned another similar undertaking—a 9-mile line, consisting of 2-inch and 2½-inch line pipe. The line was tested at frequent intervals during the progress of the work, and in one instance, when a leaky joint was detected, all the pipes were taken up and relaid as far back as the leak. Upon the completion of the first 5 miles of the line it was tested to 100 pounds air pressure, for a period of 36 hours, without developing the slightest leak. These two examples show the superiority of line pipe couplings and the advisability of using them in preference to standard couplings for high pressures.

Riveted joints are frequently used in pipe lines whose diameters are not less than 20 inches, inside measurement, this being the smallest pipe in which even an undersized riveting helper can work to advantage. The maximum head for which this type of joint

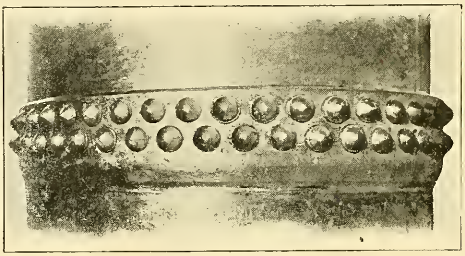


FIG. 4. EXPANDED JOINT WITH TWO ROWS OF RIVETS.

should be used is about 1200 feet, although it has been used for even higher heads. In laying riveted pipe, the lengths are riveted together after the manner of connecting the short sections in the shop, each length having a large and small end. Field riveting and calking are sometimes done by hand and sometimes by compressed air. Riveted joints are also used for lap-welded pipes. They are then termed "bump" or "expanded" joints, because one end of each pipe is upset or expanded. The expanded end is beveled for calking. Ordinarily the joints are single riveted, but when very high heads are used, requiring heavy pipe, it has been found necessary to resort to double riveting in order to make the joints tight. (Fig. 4.)

Flange joints are more expensive than the preceding types, hence their use in hydraulic work is generally confined to extraordinary pressures. The flanges are usually faced in a lathe, but this alone will not prevent leakage. The faces may be ground together until they fit so perfectly that the joint will be tight, but this

operation is very costly; hence the well-known expedient of using a filler or gasket of some pliable material—usually copper for steam pressure and rubber for hydraulic pressure. In a properly designed flange joint a small gasket may be made quite as effective as a large one, and there is no reason why it should extend outside the bolt circle.

With reference to the manner in which they are attached to the pipes, flanges may be classified as *screwed, riveted* and *welded.*

Screwed flanges of cast iron or cast steel, although largely used for steam, are rarely used for extreme hydraulic pressures, except for pipes of very small diameter. It is the practice of the Crane Company, of Chicago, in their steam-fitting business, to screw the pipe into the flanges until the ends project about $\frac{1}{16}$ inch. By means of a special lathe the projecting ends are then cut off and a light cut taken off the face of each flange to make it normal to the axis of the pipe. To prevent leakage the threads of the flanges and of the pipe should have the same taper.

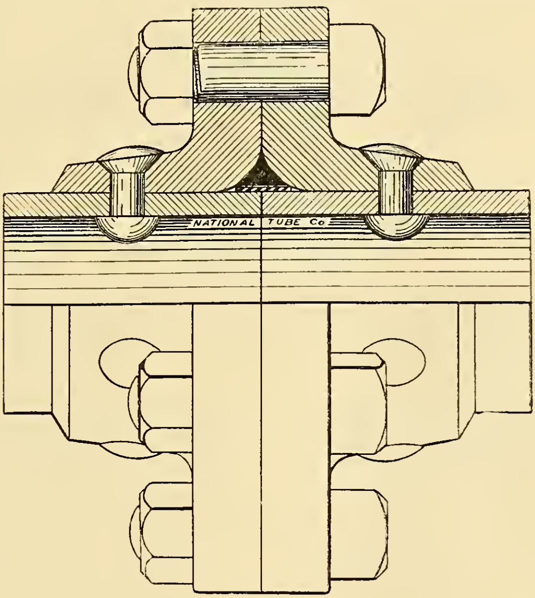


FIG. 5.

Riveted flanges (flanges riveted to the pipe) may be of cast iron, cast steel or pressed steel. They may be faced and bolted together with a gasket between (Fig. 5), or they may be riveted together as in Fig. 6, in which case they are made of pressed steel, without facing or gasket, the joints being made tight by calking the

beveled edges of the flanges. It is an excellent practice to shrink the flanges on the pipe before riveting them.

Welded flanges of forged steel form an ideal joint for high pressures. The method of welding employed by the National Tube Company consists of slipping a rough-forged steel flange over the end of the pipe, then heating both pipe and flange to the welding point, after which they are withdrawn from the forge, the flange

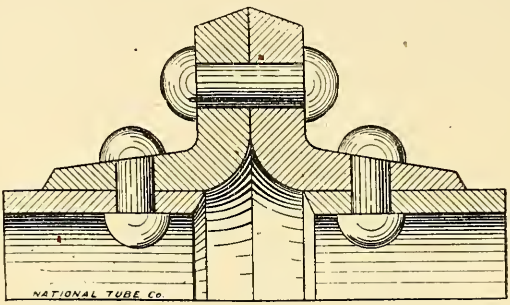


FIG. 6.

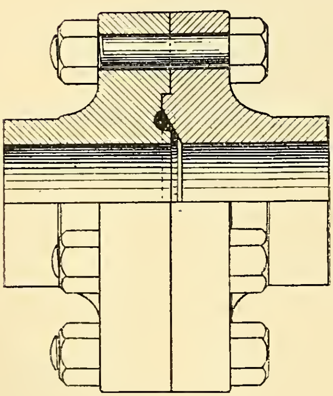


FIG. 7.

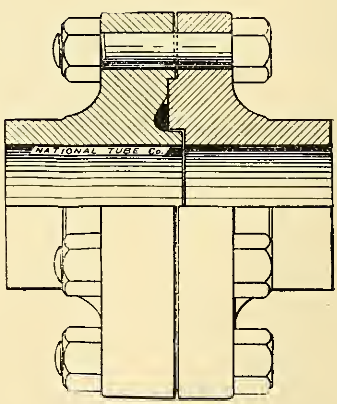


FIG. 8.

placed on an anvil and slowly revolved, while the rapid blows of a steam hammer directed against the inside of the pipe solidly weld flange and pipe together.

In Europe the welding is performed by means of the electric arc. The flange is first beveled on its inside edge, so that when it is fitted on the end of the pipe a V-shaped space is left, into which small pieces of steel are laid. These, together with the contiguous metal of both pipe and flange, are heated to a welding temperature

by the electric arc, the welding being performed by a pneumatic hammer. This operation welds the flange only about three-fourths through its thickness. The remaining fourth at the extreme end of the V-shaped filling is then burnt out next to the pipe by means of the electric arc, and filled, heated and welded in the same manner as the back of the flange.

The writer is informed that the Union Iron Works of San Francisco have a plant for welding flanges to steam pipes, but is not advised concerning the method employed.

As the solid welded flange joint is used for extremely high pressures, it is very important that the annular groove or recess in the face of one of each pair of flanges be so designed that when the flanges are bolted together the gasket cannot be forced out of its position in the groove by the pressure inside the pipe. The joint designed by Mr. W. R. Eckart for the Standard Electric Company

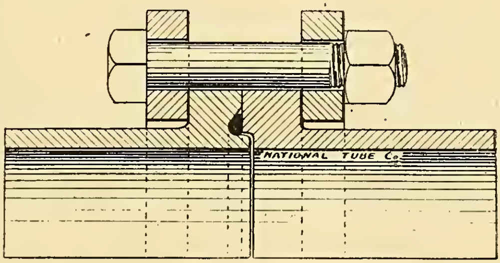


FIG. 9.

(Fig. 7) and the one designed by the National Tube Company (Fig. 8) are both in use in important pipe lines in California, and are giving excellent satisfaction. The distinctive feature of these joints is the annular groove, into which is compressed a circular rubber gasket when the flanges are drawn together. No matter how great the pressure, the gasket cannot be blown out, since the tendency is to squeeze it more tightly into the groove.

A modified form of the welded flange consists of a heavy band or ring, welded on the outside of the pipe at each end, faced and grooved in the same manner as the flanges just described. The faces are drawn together by means of bolts through a pair of loose flanges behind the rings. (Fig. 9.) This style of joint was adopted for the 5-inch pipe line at Simplon tunnel (Switzerland), operating under a maximum pressure of 2250 pounds per square inch. A similar joint is used in a power line near Vouvry, Switzerland, under a head of 3117 feet.

A FEW REPRESENTATIVE PIPE LINES ON THE PACIFIC COAST.

The following brief description of a few representative pipe lines is designed to illustrate the conditions under which hydraulic engineers have deemed it expedient to use the several types of pipes and joints referred to in this paper.

The San Joaquin Electric Company's pipe line (near Fresno) has the distinction of being the pioneer high-pressure power line of the Pacific Coast. It was constructed in 1896. Its length is 4020 feet and its total head is 1406 feet. There are 960 feet 24-inch riveted pipe No. 12 gauge steel, 860 feet 24-inch riveted $\frac{1}{4}$-inch steel, 400 feet 20-inch lap-welded $\frac{5}{16}$-inch steel with Converse joints, 800 feet 20-inch lap-welded $\frac{5}{16}$-inch steel with flange joints, and 1000 feet 20-inch lap-welded $\frac{3}{8}$-inch steel with flange joints. The flanges were shrunk on and riveted to the pipes, one of each pair being recessed, while the other has a corresponding annular projection. Each joint contains 16 bolts 1 inch in diameter. A rubber gasket was used between the faces.

During the year 1900 the Standard Electric Company constructed two parallel pipe lines for power development, each consisting of 2813 feet 48-inch wooden stave pipe, 464 feet 48-inch riveted pipe $\frac{5}{16}$-inch steel, 760 feet 30-inch cast-iron pipe with shells 1 inch, $1\frac{1}{4}$ inches and $1\frac{1}{2}$ inches thick, corresponding to 275 feet, 550 feet and 700 feet static heads, respectively, and 2365 feet 30-inch lap-welded steel pipe with shells $\frac{7}{16}$ inch, $\frac{1}{2}$ inch, $\frac{5}{8}$ inch and $\frac{3}{4}$ inch thick, depending upon the static head. The total head is 1475 feet. The joints for all of the lap-welded pipe are of the solid welded flange type. (Fig. 7.) The flanges are $2\frac{1}{4}$ inches thick. Each joint contains 32 bolts, 1 inch, $1\frac{1}{8}$ inches and $1\frac{1}{4}$ inches, the size depending on the pressure.

The Keswick pipe line of the Northern California Power Company, constructed in 1901, is 6800 feet long, and has a maximum head of 1204 feet. It consists of 800 feet 42-inch wooden stave pipe, 3600 feet 30-inch riveted No. 8 gauge to $\frac{3}{8}$-inch steel, and 2400 feet 30-inch lap-welded $\frac{7}{16}$-inch to $\frac{5}{8}$-inch steel. The lap-welded pipe has expanded joints, with 1 row of rivets for the $\frac{7}{16}$-inch and $\frac{1}{2}$-inch steel and 2 rows for the $\frac{5}{8}$-inch.

The Colgate plant of the California Gas and Electric Corporation has 5 lines of 30-inch pipe, each of which is 1625 feet long, the maximum head being 702 feet. The upper portion (680 feet) consists of riveted pipe, No. 12, No. 10 and No. 8 gauge steel, while the lower portion (945 feet) consists of cast-iron, with shells varying

in thickness from 1 inch to $1\frac{1}{2}$ inches. The cast-iron pipes are 12 feet long, the joints being of the usual bell and spigot type, filled with lead and calked in the usual way. The pipes are firmly anchored to bed rock by massive concrete piers.

The De Sabla plant of the California Gas and Electric Corporation, near the town of Chico, contains 2 parallel lines of 30-inch pipe (the first completed last year and the second now in process of construction), each 6225 feet long, consisting of 5200 feet of riveted No. 10 gauge to $\frac{9}{16}$-inch steel (maximum head approximately 1100 feet), 465 feet lap-welded $\frac{1}{2}$-inch, $\frac{9}{16}$-inch and $\frac{5}{8}$-inch steel with expanded joints (maximum head about 1300 feet), and 560 feet lap-welded $\frac{11}{16}$-inch and $\frac{3}{4}$-inch steel with solid welded flange joints. The total head is about 1500 feet.

The pipe line of the Mill Creek No. 3 plant of the Edison Electric Company, near the town of Redlands, is 8400 feet long from the forebay to the power house. There are 2485 feet 26-inch and 2150 feet 24-inch riveted steel No. 14 to No. 0000 gauge, 2830 feet 24-inch lap-welded $\frac{3}{8}$-inch to $\frac{3}{4}$-inch steel with expanded joints, and 620 feet 24-inch lap-welded $\frac{3}{4}$-inch steel with solid welded flange joints. (Fig. 8.) Near the power house the line divides into two 18-inch lap-welded $\frac{5}{8}$-inch steel branches, and each of these into two 14-inch lap-welded $\frac{1}{2}$-inch steel branches, all with solid welded flange joints. The total head is 1960 feet. The steel for the lap-welded pipe is basic open hearth, ultimate tensile strength 50,000 to 60,000 pounds per square inch, and the pipes were tested at the mill to $1\frac{1}{2}$ times the static pressures indicated by the profile.

The Standard Oil Company's pipe line, extending from the Bakersfield and Coalinga oil fields to Point Richmond on San Francisco Bay, a distance of 278 miles, was completed in 1903, and is used as a pumping main for the transportation of oil. It consists of 8-inch standard line pipe of soft open-hearth steel, ultimate tensile strength from 40,000 to 50,000 pounds per square inch. Each pipe was subjected at the mill to a hydrostatic test of 1500 pounds per square inch. The working pressure is approximately 600 pounds per square inch.

The Columbia Improvement Company have recently completed, near Tacoma, Wash., 4 lines of riveted steel pipe, each 1700 feet in length, and with a total head of 900 feet. Each line is made up of 450 feet 48-inch lap-riveted $\frac{1}{4}$-inch and $\frac{5}{16}$-inch steel, 200 feet 45-inch butt-strapped $\frac{3}{8}$-inch steel, 400 feet 42-inch butt-strapped $\frac{1}{2}$-inch steel, 400 feet 40-inch butt-strapped $\frac{5}{8}$-inch steel, and 250 feet 36-inch butt-strapped $\frac{3}{4}$-inch steel.

Although the foregoing brief description is far from being complete, it will serve to give a general idea of high-pressure practice on the Pacific Coast, which has been one of the objects of this paper.

The writer is indebted to Mr. T. W. Brooks, of the National Tube Company, for illustrations of high-pressure joints, and to Mr. G. R. Field, of the Risdon Iron Works, for information concerning the pipe lines of the Columbia Improvement Company.

VERTICAL RAILWAY CURVES.

By H. I. Randall, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 27, 1904.*]

Vertical curves in railroad work, to round off the angle made by the change in grade rate, have undoubtedly been used for many years and probably since railroads were first built; but the writer is, from personal observation, constrained to believe that many have not given some phases of the subject the careful consideration which they deserve, *e. g.*, just why they are needed and how long they should be. The practice seems to be to put in a curve generally 200 to 400 feet or more in length without any definite or adequate theoretical basis for the same. The writer proposes to consider what justification there is for this practice and to show that the advantage of increasing the length of the vertical curve is much greater with short trains than with long ones, and that it is a great advantage to have the locomotive exert as great a pull as practicable in passing sags in the grade line; in fact, that to have the locomotive exert a great pull is, at least theoretically, the most effective way to have a train pass a sag in the grade line without the cars crowding together and thereby causing a shock or jerk.

Vertical curves do or may serve a double function.

Case I.—They enable the train to pass from one grade to another without the shock which would occur with too sudden a change of the movement of the parts (as single cars) of the train in a vertical plane.

Case II.—They may keep the couplings from changing from tension to compression, and in so doing avoid a jerky movement of the train which may become so great as to break the train in two.

The following notation will be used:

L = the weight of the locomotive, in tons of 2000 pounds.

C = the average weight of 1 car and its load, in tons of 2000 pounds.

α = the pull in pounds which the locomotive is exerting for each ton of its weight.

β = the change in grade rate on the vertical curve in 1 car length. The locomotive is considered to be of the same length as a car. The length of a car, at any point on a vertical curve, and its horizontal projection are assumed to be the same; or β is assumed to be constant.

* Manuscript received June 30, 1904.—Secretary, Ass'n of Eng. Socs.

Q = the pull in pounds the locomotive must exert to keep compression from a coupling or from several couplings.

R and r = grade rates at the ends of the vertical curve.

n = the total number of cars in the train.

a = the number of car lengths the vertical curve is long.

d = the number of cars at the rear end of the train off the vertical curve.

m = the number of cars at the forward end of the train which have passed off the curve.

For Case I, suppose the locomotive (or a car), Fig. 1, in passing from the left toward the right has moved so the forward truck is at A, the end of the vertical curve AB. As it continues to move, it will rotate about the rear truck in a vertical plane, or suddenly be given an angular acceleration about that point. The magnitude of this acceleration depends upon the velocity at which the car is moving, the length of the car and the length of the vertical curve. For an abrupt and considerable change of grade rates and with a verti-

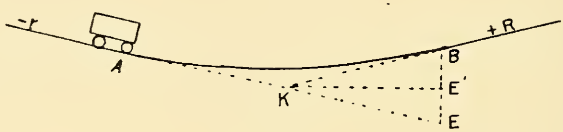


Fig. 1.

cal curve of zero length or practically so, and a high velocity, an objectionable shock would undoubtedly occur due to this acceleration. For short vertical curves and considerable change in grade rates this acceleration is not likely to be objectionable.

Assume a vertical curve, AB, joining the grades — r and + R as 100 feet long on a straight track and the change in grade rate to be 2. Draw through K, the intersection of the grades, a horizontal line intersecting the vertical through B at E′. Produce BE′ to intersect the grade — r produced at E. Then KE′ = 50 feet and BE = 1 foot. A circle tangent to the grades — r and + R at A and B respectively would be essentially coincident with the flat parabolic vertical curve AB, and BE would be essentially the tangent offset from AK for this circle in 100 feet. A circle 100 feet long and with a tangent offset of 1 foot corresponds to a 1° 09′ curve. The pressure would, of course, be normal or vertical to the track.

A horizontal curve of this degree, if the pressure is normal to the track, would be considered a very easy curve, and would give no objectionable shock due to the movement of one end of the car about the other end as the car passes on the curve; so in this case

a light curve would be less objectionable even with high speed. From this point of view very short curves satisfy all practical requirements.

Deductions could easily be made showing what this angular acceleration and the pressure would be, but even if made they would not indicate whether a certain curve were objectionable or not.

The vertical curve might be so short that the axes of adjacent cars would make so large an angle with one another that a pair of couplings that were together would slip on one another and cause them to part; but with the shortest curve which could reasonably be used on a railroad this would hardly occur.

For Case II as a preliminary to a more detailed study as to why they are needed for this purpose, a careful consideration of the movement of a train over a grade under different conditions is desirable.

As is well known, the grade of repose for a railroad train is, for any given velocity, that grade down which a descending train

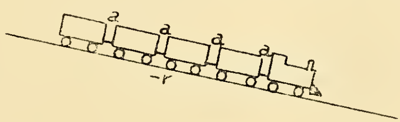


FIG. 2.

will roll indefinitely without increasing or decreasing its velocity. The grade of repose quite rapidly increases as the velocity increases if the velocity is greater than about 8 miles per hour. Also the grade of repose for the locomotive, loaded and unloaded freight cars and passenger cars is somewhat different, but as matters are simplified by assuming that it is the same for all parts of any train, and as it seems impracticable to consider it otherwise for our purposes, and as it leads to no material error, we will so consider it.

When a train moves over a track its movement is affected by the value of the grade of repose and by the actual grade. The effect of the grade of repose on its movement is the same whatever the actual grade on which the train happens to be. It is the same for all parts of the train (with the assumption above) and simply changes with the velocity. The effect of the actual grade on the velocity is definite and can be easily calculated.

Suppose the locomotive and a train of cars, Fig. 2, are running down a grade, — r, and that the locomotive is *not* working. If the rolling resistance is the same per ton for the locomotive and cars, evidently there will be no tension in the couplings, a, a. The veloc-

ity of the train will be affected by the grade of repose and the actual grade.

If r is less than the grade of repose for the moving train, the train will be decreasing in velocity, but without making the couplings, a, a, tension or compression. As the grade of repose is less for low than for high velocities, it is entirely possible for the velocity, if high, to decrease until the grade of repose for the decreased velocity becomes equal to r, when the train will continue indefinitely at that velocity or until r changes. If the grade of repose of the moving train when at its least value is greater than r, then the train will decrease in velocity until it stops. If r is greater than the grade of repose for the moving train, the velocity of the train as a whole will increase until the grade of repose has risen to r, when the velocity will remain constant, or r changes.

If the locomotive *is at work* while running down the grade, all the couplings will be in tension, the one immediately back of the locomotive will have the greatest tension, and they will gradually decrease until the one in front of the rear car is reached, where the

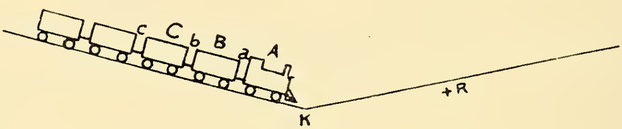


FIG. 3.

tension will be the least. As far as velocity is concerned, the effect of the locomotive working in running over any grade is just the same as though r were increased if r is a minus or a down grade, and decreased if r is a plus or an up grade. The amount of this increase or decrease is practically 1 foot for each 20 pounds tractive force the locomotive exerts on each ton of the train including the locomotive. This is true because the accelerating force due to gravity on the grade r is almost exactly 20 r pounds per ton (2000 pounds) of train. On a uniform grade of indefinite length, the velocity would decrease to zero or change until the r as in effect changed by the constant force exerted by the locomotive became equal to the grade of repose, when the velocity would remain constant.

Now let us advance a step and see what takes place when the train passes from one grade to another, as shown in Fig. 3. Suppose the train is moving down grade — r at a uniform velocity and that the locomotive is *not* working. There would be neither tension nor compression in the couplings, a, b, etc. The moment the locomo-

tive reaches the grade R or passes K it would begin to decrease in velocity, and the couplings, a, b, c, etc., would become compression. Assuming that the velocity is such that the whole train will pass K, and that R is a plus or up grade, it would be only a question of a short time when the train would be brought to a stop, and in doing so the couplings would become compression, but with a shock. If r is great enough the train would roll back, but with no shock, as the locomotive and cars would stop and begin the backward movement at the same time; and if the grade of repose was the same for the locomotive and cars, the couplings would, after yielding the compression of their springs, be neither in tension nor compression. In practice, probably, they would change locally from compression to tension, but that only slowly.

If the locomotive is working when it reaches K, the results would be different. There would be tension in a, b, c, etc. When the locomotive has passed K, whether there is tension in the couplings or not depends upon how much the locomotive is working.

In order to have the locomotive, when entirely on grade R, move at the same velocity as the cars B, C, etc., entirely on grade r, the force exerted by the locomotive, upon itself in this case, must evidently be 20 (R — r) L pounds at least. The locomotive would be doing work at the rate of 20 (R — r) Lv foot-pounds per second if v is the velocity in feet per second. While the locomotive is passing K, if it is to have the same velocity as the cars the force exerted by the locomotive must be at least something between 20 (R — r) L and zero. The exact amount at any instant depends upon just how much of the locomotive has passed K. If the locomotive was exerting a force of just 20 (R — r) L when it had just passed K, there would be no tension in any of the couplings. If the locomotive is exerting a force less than this amount, the car B will crowd on the locomotive, and a moment later the car C would crowd up and the couplings would change from tension to compression, one at a time. Of course, this action is only momentary, for as soon as B passes K the conditions have changed. If when the locomotive has just passed K it is exerting a force greater than 20 (R — r) L, all the couplings, a, b, c, etc., would be in tension.

Now, assume the car B has just passed K and that the locomotive and the car B are on grade R while the rest of the train is on grade r. If the locomotive, A, and the car, B, are to move at the same velocity as the remainder of the train, the locomotive must evidently exert a force of at least 20 (R — r) (L + C). If the force exerted by the locomotive is less than this, the car C will first crowd on B, and the coupling, b, will become compression. The

cars C, D, etc., would soon crowd ahead if the conditions were not changed by the movement of the train. If the force exerted by the locomotive was greater than 20 (R — r) (L + C), all the couplings would be in tension, but decreasing in amount in passing from the head to the rear of the train.

If Q is the force the locomotive must exert to keep compression from all the couplings when the locomotive and n cars are on the grade R, then $Q = 20\ (R - r)\ (L + nC)$. With the locomotive exerting a force greater than this, the movement of the train as a whole, as regards change in velocity while on grades r and R, is exactly the same as though the whole train were on r, as before explained, and the locomotive was exerting a force equal to the actual force less Q. If the force exerted by the locomotive is sufficient to haul the train up the grade R, but is so small that all or part of the couplings become compression, and the whole train has passed K, then there is a time when the rear cars will have de-

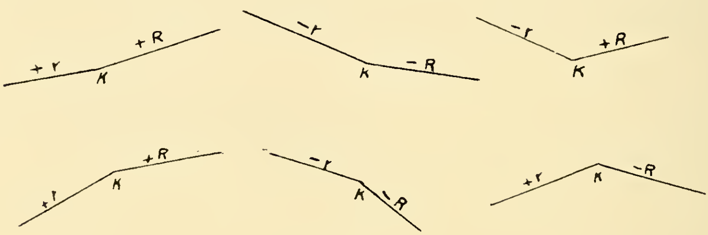


FIG. 4.

creased in velocity, so that momentarily the different parts of the train will be moving at different velocities, the front faster than the rear. This will cause the couplings to change from compression to tension. First one coupling near the front end will change as the locomotive pulls out, and an instant later the next to the rear of this. As each change takes place there is a jerk. This jerk becomes greater as each succeeding coupling changes from compression to tension, and may become so great as to break the train in two. To assist in avoiding this action is at least one of the purposes of the vertical curve.

If the locomotive is always working sufficiently to keep all couplings in tension when passing a sag in the grade line, just what the grade of repose happens to be for the particular velocity of the train is not material, as in this case the locomotive overcomes the effect due to change in grade rate. When the locomotive is not working sufficiently to gain this end, the movement of the rear end of the train is affected by the grade of repose and the actual grade,

while the front end is affected by the grade of repose, the actual grade and the pull of the locomotive. The resultant effect will be for the rear part of the train to crowd upon the forward part.

In order to have the above formulæ general, notice grades R and r must be used with the proper signs. When R and r have such signs that (R — r) is plus, the locomotive must exert a force to pull the train ahead to keep compression from the couplings. When (R — r) is minus, the locomotive need not work to keep the compression from the couplings, for then the forward part of the train will tend to move faster than the rear part on passing the point where the grade rate changes. Grades like Fig. 4a give (R — r) plus, while grades like Fig. 4b give (R — r) minus.

There would be no change from tension to compression in the couplings in passing K when (R — r) is negative, whether the locomotive is working or not. Therefore, theoretically, it is not essential to use a vertical curve to keep the couplings from changing

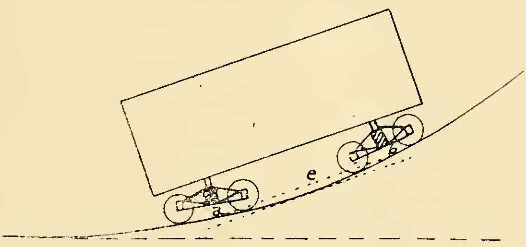


Fig. 5.

from plus to minus in passing such a place. While theory does not require one, it is, nevertheless, common practice to put one in whether (R — r) is plus or minus, and properly so, in order not to have the change in the amount of tension in the couplings so sudden as to cause a jerk. The case where (R — r) is minus will not be further considered.

By a line of reasoning similar to the above and more extended, a determination can be made of the proper length of the vertical curve, or the allowable change in grade rate per station, based on the condition that the cars shall never crowd upon one another.

Assume the vertical curve to be a parabola, which is in conformity with the usual practice. The front and rear trucks of any car on the curve will be on different grades. At any instant each car and the locomotive will have a double movement; first, one of rotation in a vertical plane, and second, one of translation in the direction of the line joining points below the two pairs of trucks, as more definitely defined below, for the cars or similar points for the locomotive.

The first motion is that considered in Case I. For the second, the movement of any car will be essentially the same as though both trucks of that car, Fig. 5, were on a grade equal to the grade of the tangent to the parabola under the middle, e, of a line, ab, extending from center to center of the wheel bases of the trucks of the car or similar points for the locomotive. At this point the grade rate of the tangent to the parabola is the mean of the grade rates of the tangents to the parabola under the centers of the two trucks, or at the points a and b. So it will be assumed that the grade on which any car or the locomotive is moving is the grade under the middle point of the line, defined above, joining the wheel bases, and the problem becomes one of considering the action of the train in passing from grade r over a series of grades, the vertical curve, to the grade R. Each grade would be one car-length long, and of a rate which is that under the middle of the particular car.

Consider, first, the case where the train is *so short that the whole of it can be on the vertical curve at the same time.* Let the train approach the curve from the left, Fig. 6, and assume that the locomotive and h cars are just on the curve, or the coupling, e, is just over P. Then due to the action of the grades under the respective cars and the locomotive, all the cars to the left of P will move at the same velocity; E will move slower than F, D slower than E, C slower than D, etc. The grade rate under the car E will be $-r + \frac{\beta}{2}$. The force, $\underset{\sim}{Q}$, necessary to be acting on E to keep its velocity the same as F, and therefore compression from e, is

$$20\left[\left(-r+\frac{\beta}{2}\right)-(-r)\right]C = 20\frac{\beta}{2}C.$$

This is really the force that must act along the axis of the car, but this force is practically equal to $\underset{\sim}{Q}$ in each case, and is so assumed. The grade rate under D is $-r + \frac{3}{2}\beta$, so at the same time the $\underset{\sim}{Q}$ to act on D to keep compression from d and e is $20\frac{3}{2}\beta C$, and similarly for each successive car to the right. $\underset{\sim}{Q}$ for the locomotive will be $20\frac{2h+1}{2}\beta L$. From this it is easily seen that $\underset{\sim}{Q}$ for the whole train will increase as the train moves to the right until at least all but one car has passed the point P as in Fig. 7. When in this position, $\underset{\sim}{Q}$ for F would be $\frac{20\beta}{2}C$; for E, $20\times\frac{3}{2}\beta C$; for D, $20\times\frac{5}{2}\beta C$, etc., and for the locomotive $20\frac{2n-1}{2}\beta L$.

When G has just passed P, Fig. 8, (also with the whole train at any position on the vertical curve) Q for F, to keep compression from f, is $20 \beta C$; for E, to keep compression from f, is $20 \times 2 \beta C$, etc.; and for the locomotive, to keep compression from f, is $20\, n\, \beta\, L$,

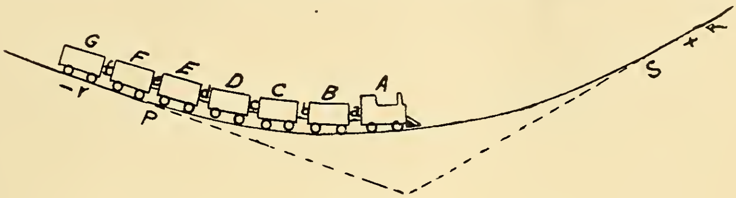


FIG. 6.

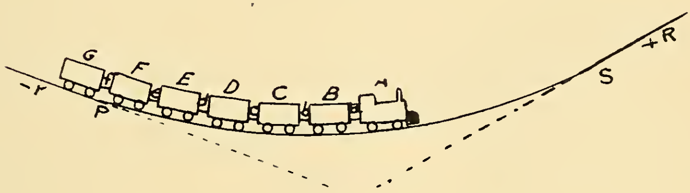


FIG. 7.

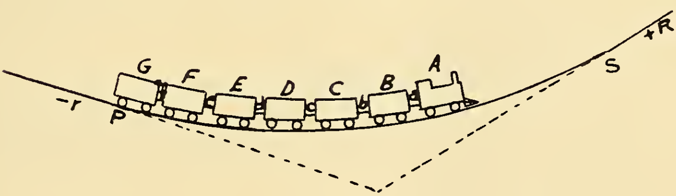


FIG. 8.

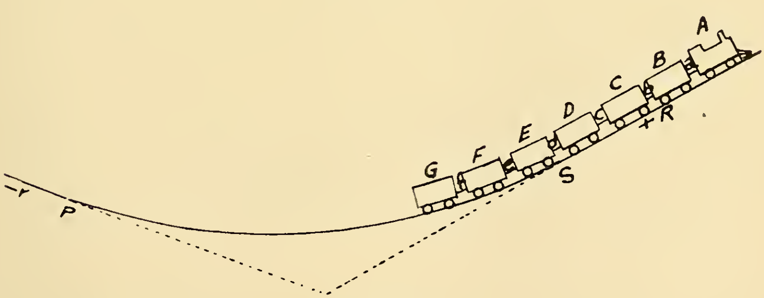


FIG. 9.

or for the locomotive and every car the demand on the locomotive is greater than when the train is in the position shown in Fig. 7. Then for the whole train, when in this position, to keep compression from f,

$$Q = 20\beta\,[\,(1 + 2 + 3 \,.\,.\,.\,.\,.\,.\,(n - 1)\,)\,C + n\,L]$$

$$= 20\beta\left[\frac{n\,(n-1)}{2}\,C + n\,L\right] \qquad (1)$$

If the locomotive and m cars have passed off the vertical curve to the right, Fig. 9, then Q for F, to keep compression from f, is $20\beta C$; and Q for E, to keep compression from f, is $20 \times 2\beta$ C, etc. Q for each car to the right of S is $20\,(n - m - \frac{1}{2})\,\beta$ C and Q for the locomotive is $20\,(n - m - \frac{1}{2})\,\beta$ L. Then for the whole train, when in this position, to keep compression from f,

$$Q = 20\beta\left[(1 + 2 + 3 \,.\,.\,.\,.\,(n - m - 1)\,)\,C + \left(n - m - \frac{1}{2}\right)(m\,C + L)\right]$$

and hence

$$Q = 20\beta\left[\frac{(n-m)\,(n-m-1)}{2}\,C + (n - m - \frac{1}{2})(m\,C + L)\right] \quad (2)$$

By multiplying out,

$$Q = 20\beta\left(\frac{1}{2}\left[n\,(n-1) - m^2\right]C + (n - m - \frac{1}{2})\,L\right) \quad (3)$$

In this equation, notice the coupling, f, must be on the curve or $m \leqq (n - 1)$. When $m = n$ the coupling, f, has passed off the curve and the equation does not hold.

From equation (3) it is easily seen that as m increases, Q, or the demand on the locomotive, decreases. When the last car has passed off the curve, the locomotive need exert no pull to keep compression from the couplings.

When the train is of such length that the whole of it can be on the vertical curve at one time, by comparing equations (1) and (3), in which m equals zero, it is seen that the greatest demand on the locomotive occurs when the train is entirely on the vertical curve. It is also easily seen that the demand on the locomotive to keep compression from all the couplings, when the whole train is in any position on the vertical curve, is that given in equation (1). Therefore the exact position of the train on the curve is immaterial.

In equation (1), solve for β after making $Q = \alpha$ L, and get

$$\beta = \frac{\alpha\,L}{20\left[\frac{n\,(n-1)}{2}\,C + n\,L\right]} = \frac{\alpha}{20\left[\frac{n\,(n-1)}{2}\,\frac{C}{L} + n\right]} \quad (4)$$

This shows the maximum permissible change in the grade rate per car length in order never to have compression in any of the couplings. Notice the train, as a whole, may be increasing or decreasing in velocity, and that any force the locomotive exerts above

Q affects the train as a whole to accelerate its velocity, or, if not large enough for this, to keep the train from decreasing in velocity as fast as it otherwise would, due to the normal train resistance.

If the train is so long that it may more than cover the whole curve, which would, in practice, be the most common case, then as

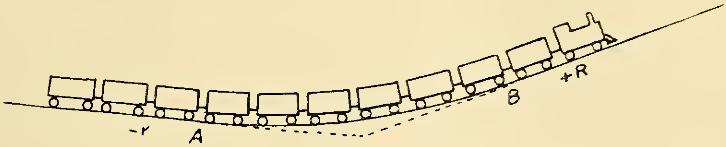


Fig. 10.

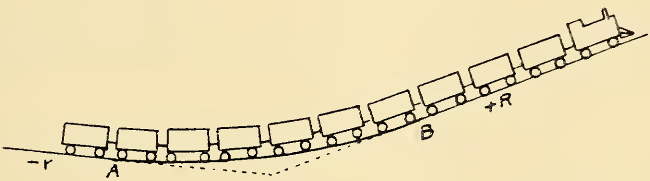


Fig. 11.

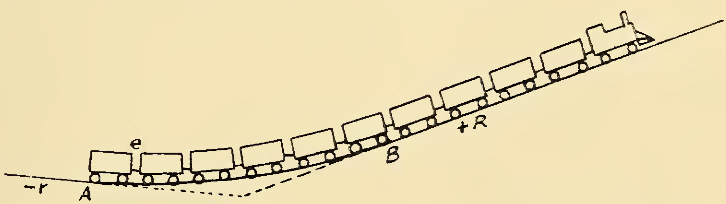


Fig. 12.

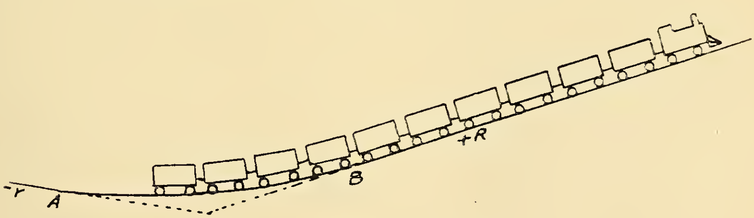


Fig. 13.

the train passes from the left toward the right it would occupy some such position as that shown in Fig. 10. Notice as the locomotive passes A, moving from the left toward the right, the Q required to keep compression from the couplings before the locomotive reaches B is as discussed above, and as shown in Fig. 6. After the locomotive has passed B, if compression can be kept from

the coupling over A, none of the cars to the rear of A will crowd up to those ahead of A. With the train in the position shown in Fig. 10, the value of αL must be at least equal to $\underset{\sim}{Q}$ to keep compression from the coupling at A. In this case

$$\alpha L = 20\beta\left[\left(\frac{1}{2}+\frac{3}{2}+\frac{5}{2}\ \cdots\ \frac{2a-1}{2}\right)C + aC(n-a-d)+aL\right]$$

$$= 20\ \beta\left[\frac{a^2 C}{2} + a\,C\,(n-a-d) + a\,L\right] \qquad (5)$$

Substituting for β its value, $\frac{R-r}{a}$,

$$\alpha L = 20\,(R-r)\left[C\,n + L - \frac{a\,C}{2} - C\,d\right] \qquad (6)$$

For any positive value of a, αL evidently has a maximum positive value when d is as small as possible, which in this case would be 1 (see Fig. 11). Making d equal to 1,

$$\alpha L = 20\,(R-r)\left[C\,n + L - \frac{a\,C}{2} - C\right] \qquad (7)$$

Solving for a,

$$a = 2n - 2 + \frac{2L}{C}\left(1 - \frac{\alpha}{20\,(R-r)}\right)$$

$$= G - 2 \qquad (8)$$

where

$$G = 2n + \frac{2L}{C}\left(1 - \frac{\alpha}{(20\,R-r)}\right)$$

Notice a must be less than n, as it was so assumed in deducing the equation.

If the rear car has just passed A, the train will be in the position shown in Fig. 12. With the train in this position, the value of αL must be at least equal to $\underset{\sim}{Q}$ to keep compression from the coupling at e. In this case,

$$\alpha L = 20\,\beta\left[(1+2+3\ \cdots\cdots\ (a-1))\,C + \frac{2a-1}{2}\right.$$

$$\left.(n-a)\,C + \frac{2a-1}{2}\,L\right]$$

$$= 10\,\beta\left[a(a-1)C+(2a-1)(n-a)C+(2a-1)L\right] \qquad (9)$$

$$= 10\,\beta\left[(2a-1)\,(n\,C+L) - a^2\,C\right] \qquad (10)$$

Substituting for β its value, $\frac{R-r}{a}$,

$$\alpha L = 10\,\frac{R-r}{a}\left[(2a-1)\,(n\,C+L) - a^2\,C\right] \qquad (11)$$

Solving for a,

$$a = \frac{G}{2} \pm \sqrt{\left(\frac{G}{2}\right)^2 - \left(n + \frac{L}{C}\right)} \qquad (12)$$

This value of a represents the length of the vertical curve necessary to keep compression from the coupling between the two rear cars when the rear one has just passed on the curve.

If the train is moving off the curve to the right, equation (10) will give the value of α L or $\underset{\sim}{Q}$ to keep compression from the coupling between the two rear cars, and therefore all other couplings, if we replace a by a′ where a′ represents the number of cars remaining on the curve at the rear end of the train, Fig. 13. If $\underset{\sim}{Q}$ and a′ be considered as variables, and β and n as constants in equation (10) where a′ has replaced a, and then this expression be differentiated, we have

$$d\,\underset{\sim}{Q} = 20\,\beta\,(n\,C + L - a'\,C)\ d\,a'.$$

As n C is always larger than a′ C, the expression n C + L — a′ C is always positive. This shows that as a′ decreases, or as a′ receives a negative increment, that $\underset{\sim}{Q}$ will also decrease. Therefore, the demand on the locomotive to keep compression from all the couplings is less with the train as shown in Fig. 13 than as in Fig. 12, and the locomotive must exert its maximum pull to keep compression from the couplings when the train is in the position shown by either Fig. 11 or Fig. 12. This applies to the train when it is so long that it more than covers the vertical curve.

A careful study of these equations shows certain interesting things and develops certain practical limitations. Subtracting the value of a in equation (12) from its value in equation (8) gives

$$10\,\beta[L + C\ (n - a) - a\ C] \qquad (13)$$

L + C (n — a) and a C are the weights of the parts of the train off and on the curve, respectively; so this shows that with any curve of length a, when more than half the weight of the train is off the curve, the $\underset{\sim}{Q}$ is larger with the train as shown in Fig. 11 than as shown in Fig. 12; but when more than half of the weight of the train is on the curve, $\underset{\sim}{Q}$ is larger with the train as shown in Fig. 12 than as shown in Fig. 11.

Placing the value α L in equation (7) equal to that in equation (11) and solving for a, we have,

$$a = \frac{1}{2}\left(n + \frac{L}{C}\right) \qquad (14)$$

This is the value of a for which the demand on the locomotive to keep compression from all the couplings will be the same, whether

the train is in the position shown in Fig. 11 or Fig. 12. This special value of a is only dependent upon n and $\frac{L}{C}$. It is the same whatever the value of α and (R — r). If this value of a be substituted in either equation (8) or equation (12) and then the equation be solved for n, we shall have,

$$n = \frac{\alpha L}{15 C (R - r)} + \frac{4}{3} - \frac{L}{C} \qquad (15)$$

This gives the number of cars in the train when the required curve length is the same by equation (8) and equation (12) for any assumed value of α, L, C and (R — r).

Consider equation (12) in detail. The quantity $\left(n - \frac{L}{C}\right)$ is always plus. In order to have equation (12) give a *real* value of a, the quantity under the radical must be real. In order to have it real $\left(\frac{G}{2}\right)^2$ must be $\geqq n + \frac{L}{C}$. Placing $\left(\frac{G}{2}\right)^2 = n + \frac{L}{C}$, we have $\frac{G}{2} = \pm\sqrt{n + \frac{L}{C}}$. The value of $\frac{G}{2}$ cannot be less than this and have the quantity under the radical real.

The quantity G, which equals $2n + \frac{2L}{C} - \frac{\alpha L}{10 C (R - r)}$, can easily be either plus or minus in the limits of the problem. If α is zero, it is plus. α can be practically any value from zero to 400 or 500. $\frac{L}{C}$ will be large if the train is made up of light cars and a heavy locomotive. (R — r) can have any positive value (see page 141). In order to make G negative, it is necessary to have $\frac{\alpha L}{10 C (R - r)} > 2n + \frac{2L}{C}$, which is easily done, as, for example, let α equal 300, $\frac{L}{C}$ equal 8, (R — r) equal 0.2 and n equal 10, when G becomes — 1164. This, of course, would make $\left(\frac{G}{2}\right)^2 > n + \frac{L}{C}$, which is necessary to have the quantity under the radical real, and therefore a real value of a.

Suppose $\frac{G}{2}$ has any value $\geqq \sqrt{n + \frac{L}{C}}$, and is either plus or minus, then its square would be $\geqq n + \frac{L}{C}$, and would be plus. But whatever its numerical value, if from it we subtract the second part of the quantity under the radical, or $n + \frac{L}{C}$ the difference will be

less than the value of $\left(\frac{G}{2}\right)^2$. Therefore the part under the radical would be greater than $\frac{G}{2}$, which would make the value of a by equation (12), if a real value, a negative quantity if $\frac{G}{2}$ is minus, and positive if $\frac{G}{2}$ is plus, whatever the sign before the radical. Also, from what has been said, it is readily seen that as $\frac{G}{2}$ can be either plus or minus, so equation (8) can give either a plus or a minus value for a, but always real. Any combination by which we obtain a negative value of a for both equation (8) and equation (12) means that no vertical curve is necessary to keep compression from the couplings, and that the pull of the locomotive is being used, in addition to keeping compression from all the couplings, to overcome the normal train resistance in whole or in part, or even to accelerate the velocity of the train, so we are only practically concerned with cases giving positive values of a.

To find whether a by equation (8) or by equation (12) is the larger when the value of a is positive, let a by equation (8) equal a_8, and a by equation (12) equal to a_{12}, and call $s = a_8 - a_{12}$, then

$$s = \frac{G}{2} - 2 - \sqrt{\left(\frac{G}{2}\right)^2 - \left(n + \frac{L}{C}\right)} \qquad (16)$$

Differentiating, we have

$$d\,s = \frac{1}{2}\left(1 - \frac{G}{\sqrt{\left(\frac{G}{2}\right)^2 - \left(n + \frac{L}{C}\right)}}\right) d\,G \qquad (17)$$

It has been shown above that to make a positive, G must always be positive, and that $\sqrt{\left(\frac{G}{2}\right)^2 - \left(n + \frac{L}{C}\right)}$ is always less than $\frac{G}{2}$;

therefore $\dfrac{\frac{G}{2}}{\sqrt{\left(\frac{G}{2}\right)^2 - \left(n + \frac{L}{C}\right)}}$ is always greater than 1, and

it follows that $1 - \dfrac{\frac{G}{2}}{\sqrt{\left(\frac{G}{2}\right)^2 - \left(n + \frac{L}{C}\right)}}$ is always negative for any

value of $\frac{G}{2}$ for which a is positive. Therefore if G be given an increment, d G, the corresponding increment of s, or d s, will be negative. At some point $a_8 - a_{12}$, or s, is zero, or when

$n \doteq \frac{\alpha L}{15 C (R - r)} + \frac{4}{3} - \frac{L}{C}$; so for any value of G less than that value for which $a_8 = a_{12}$, or $s =$ zero, s must have been plus in order to have negative increments make it equal to zero, and therefore, for any value of G greater than that for which $a_8 = a_{12}$, s will be negative.

In applying the formulæ to determine values of a, certain values would be assigned to n, α, L and C or $\frac{L}{C}$. Then of the terms in the value of G, or $2\left[n + \frac{L}{C} - \frac{\alpha L}{20 C (R - r)}\right]$, $(R - r)$ would be the only variable. Under these conditions, G receives a positive increment only when $(R - r)$ increases; therefore when $(R - r)$ is less than that value for which $a_8 - a_{12}$ is made zero, a_8 will be larger than a_{12}, and when $(R - r)$ is greater than that value for which $a_8 - a_{12}$ is made zero, a_{12} will be greater than a_8. To determine theoretically the proper length of vertical curve to be put in, the larger of the two quantities a_8 and a_{12} should be used.

A graphical representation is often clearer than a mere inspection of equations. For this reason diagrams have been constructed for equations (4), (8) and (12) with assumed values of $\frac{L}{C}$ and α. An inspection of equation (8) shows that if we wish to assume values of L and C to give rather large values of a, L must usually be rather small, and C large, as, except for small values of α, $\frac{\alpha}{20 (R - r)}$ would be negative. Probably $\frac{L}{C} = 2$, the value used, would be a fair one. α is taken as 100, 200, 300 and 400. In assigning these values to α, the tender has been considered the same as a car and not included in L. If the tender is included in L, the values of α should be taken smaller. As L includes the weight of the pilot as well as the weight on the drivers, $\alpha = 400$ would correspond to a coefficient of adhesion of about 0.25.

The diagrams are largely self-explanatory. Fig. 14 gives maximum values of β, in order never to have compression in the couplings, for values of n and α from equation (4). With this equation, of course, a cannot be given, as the train does not cover the whole curve. Fig. 15 gives values of a, in order never to have compression in the couplings, for values of $(R - r)$ and α by equation (8), and also shows when a, by equations (8) and (12), has the same value (at all points on lines marked A). Equation (12) is plotted on Fig. 15 for $\alpha = 200$ for two values of n as dotted lines. This shows how little difference there is between values of a, by equations (8) and (12), when (12) gives the larger value. As equations (4) and (8)

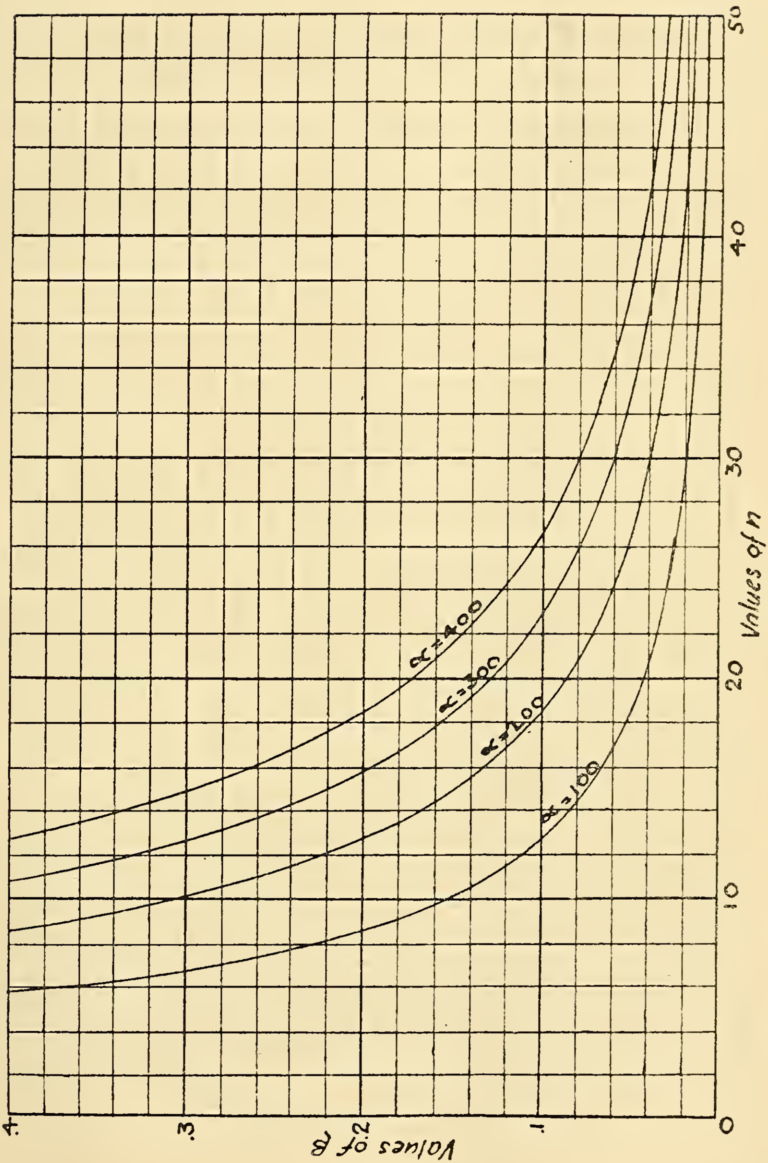


FIG. 14.

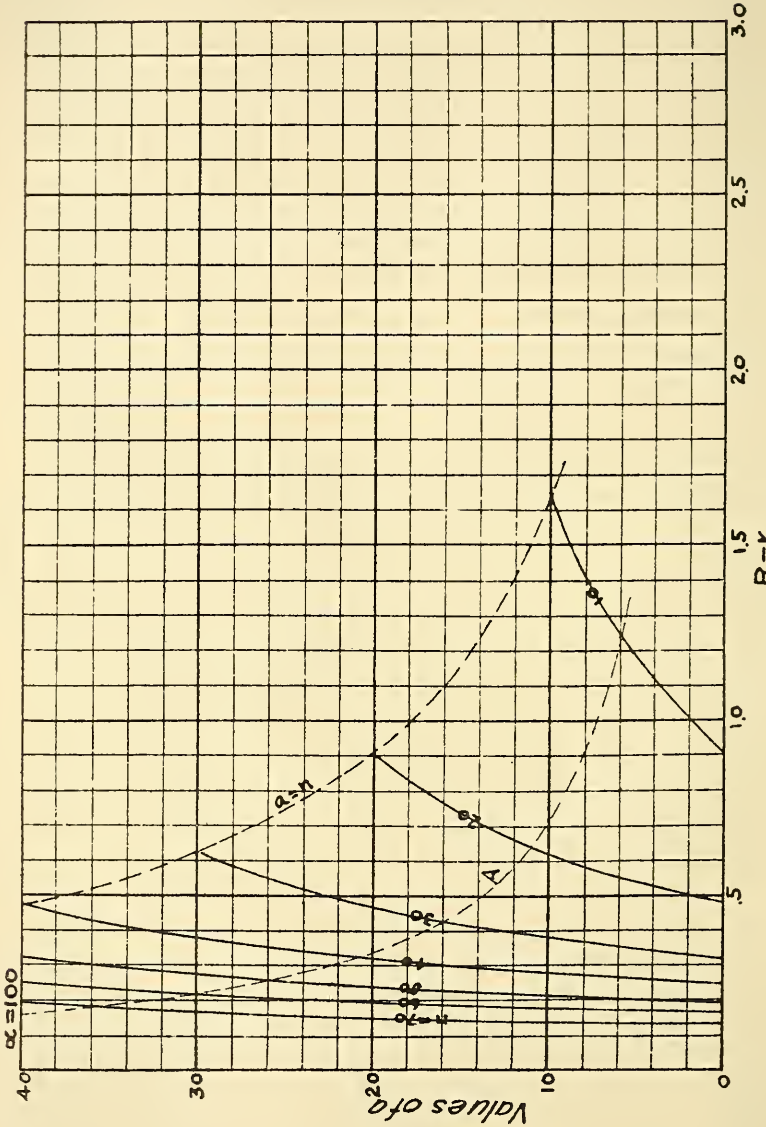


FIG. 15-α = 100.

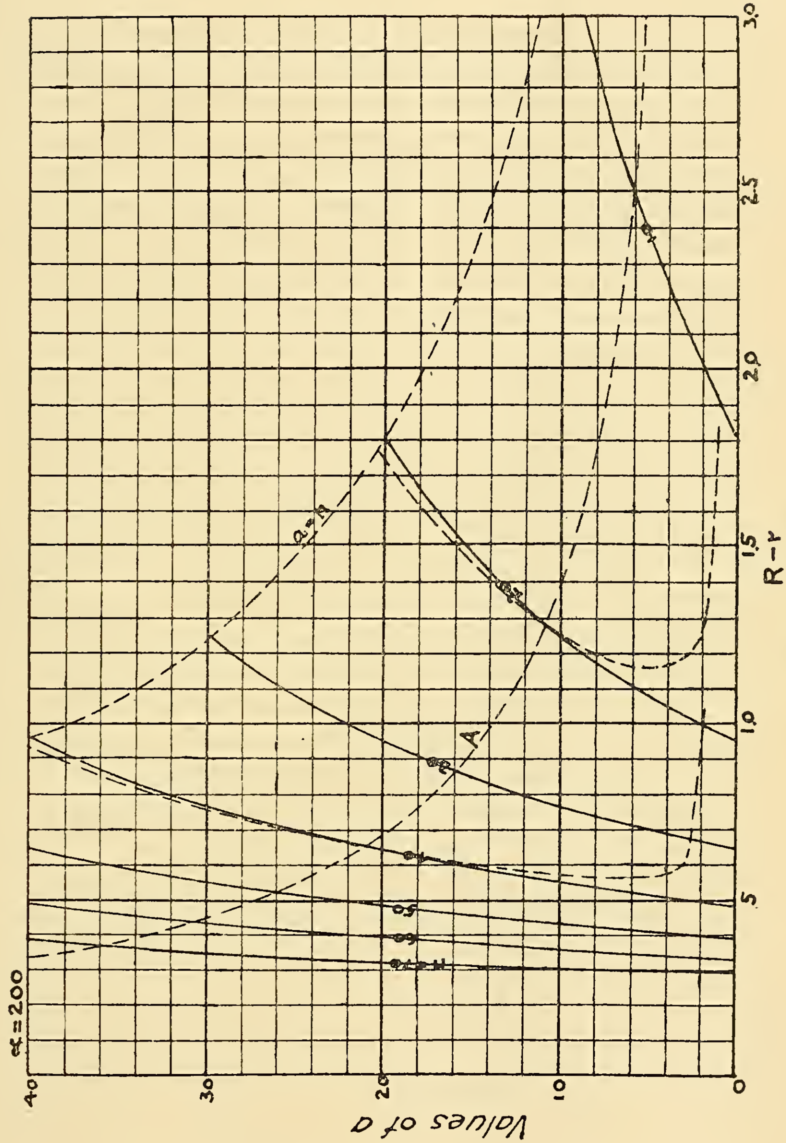


FIG. 15-$\alpha = 200$.

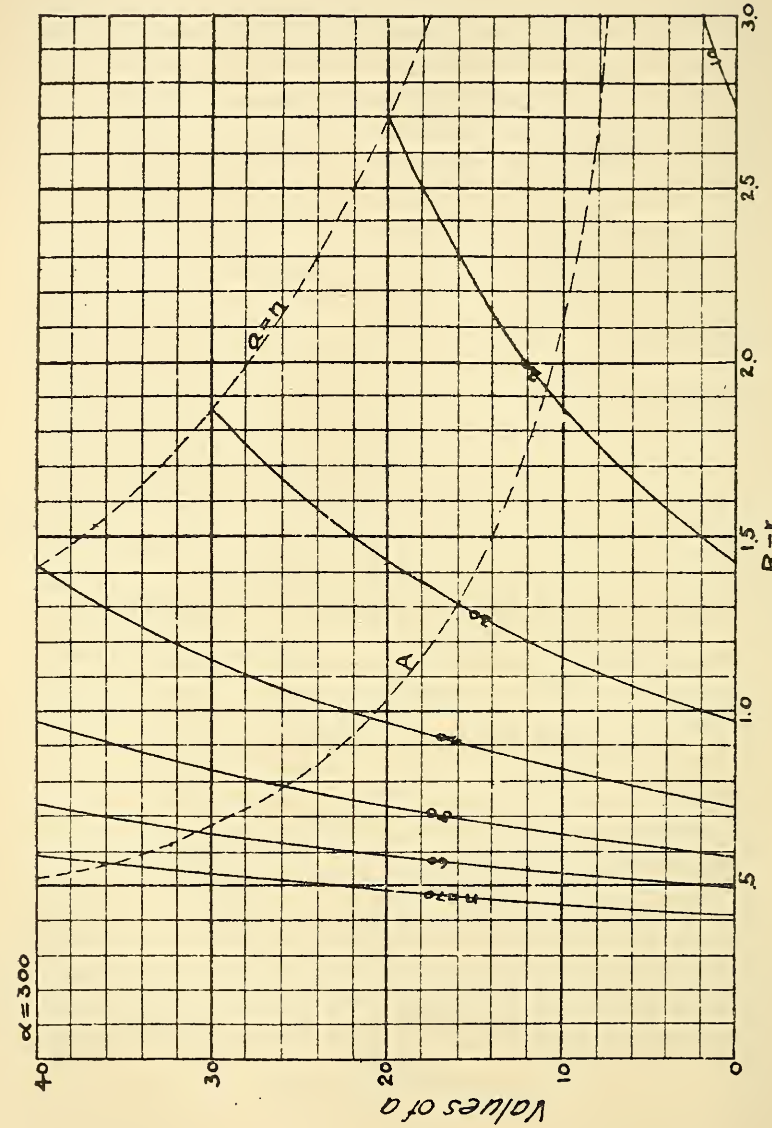


FIG. 15-α = 300.

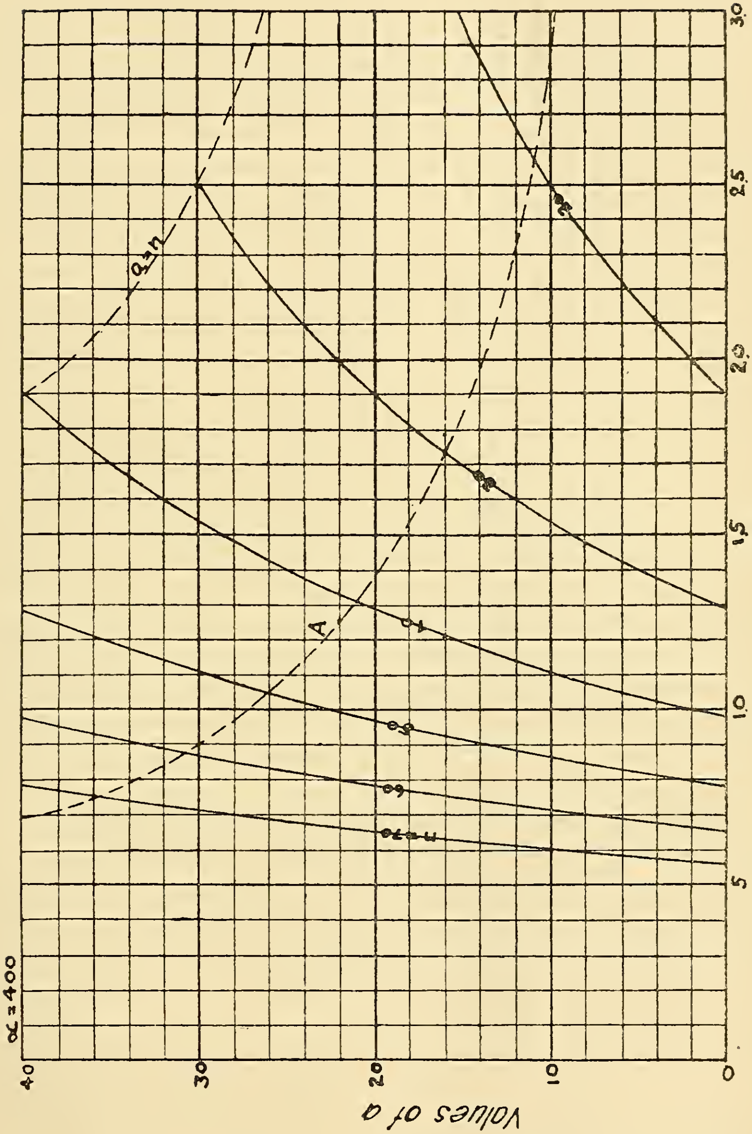


FIG. 15-α = 400.

are of sufficient range to cover the most usual cases that would occur in practice, and are simpler than equation (12), a study of them, or their graphical representations, will satisfy all practical requirements.

Fig. 15, in particular, shows that in passing sags, vertical curves of lengths ordinarily used have a very small effect in keeping compression from the couplings of long trains, and that it is only when the trains become short that the vertical curves have any considerable effect for this purpose. For instance, from Fig. 15, when $a = 300$ and $n = 40$, we may have a change in grade rate of nearly 0.75 and no vertical curve, and yet have no compression in the couplings. With a curve 12 car-lengths long, this change in rate could be increased to about 0.85, or the effect of the curve is small. If $n = 20$, a change in the grade rate of 1.45 can be made with no vertical curve; while with a curve 12 cars long, the change can be 2, or the effect when the train is short is much greater than when the train is long. Moreover, it can be seen that a relatively small increase in a would enable the change in grade rate to be increased as much. To have the locomotive pulling hard in passing the sag is much more effective in keeping all couplings in tension. This shows why "pulling out" by the engineer at such places is productive of good results. Brakes set on the cars *at the rear end of the train* would also be effective, as this would keep the rear cars from crowding upon the forward ones. But it would hardly be practicable in ordinary service to set the brakes on the rear of the train, and on the rear only, at such places. Atmospheric resistance from suction on the rear car of the train would have a similar effect to that of applying the brakes on the rear car of the train.

It is very probable that no serious jerk would occur even if there were momentarily a small compression on the couplings at a few of the cars in the train, and so it is very likely that curves considerably shorter than those shown to be theoretically necessary would satisfy all practical requirements.

CONCRETE-STEEL.

By M. C. Couchot, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 27, 1904.]

The aim of this paper is to bring before the members of the Technical Society a short description of this new and promising system of construction and some of its recent applications in the United States, and to show some of its prominent advantages.

Concrete-steel, as its name implies, consists of the combination of (1) concrete with (2) steel or iron; two very different materials—one ideal for compression, the other ideal for tension, and using the qualities and properties of both to the greatest advantage and economy.

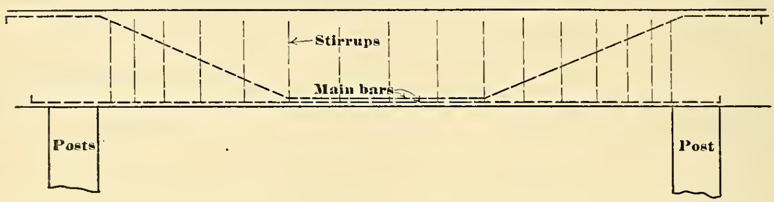
There is no doubt that the combination of these 2 materials was made years ago, but it is only of recent date that a systematic application has been used. Twenty and some years ago, Jean Monier conceived the idea of making some flowerpots of beton with a wire netting imbedded in the beton. These flowerpots were satisfactory. Then he made some water pipes, also some floor slabs, and obtained certain patents which were afterward exploited by the firm of Wayss, of Berlin and Vienna. This firm began to make some practical experiments, and to them we are indebted for the first tangible information regarding the internal work of concrete-steel. The Monier system then began to be extensively used in Europe, but principally in Germany and Austria.

This success brought others into the field, and very soon we had a number of different systems—some simple, some complicated.

About that time, 1886-87, Messrs. Ransome, in the United States, and Hennebique, in France, began the construction of floors of a larger span than had ever been attempted before. Their systems were practically identical, Mr. Ransome using square rods previously twisted and Mr. Hennebique using plain round rods. Mr. Ransome was then in California, and the work he left behind him attests his sound judgment, for at that time the theory of concrete-steel was still in embryo.

From the floor slabs to the beams there was but one step. At first the beam was treated as a narrow strip of slab having sufficient reinforcement at the lower portion to take care of the tension strains, the concrete taking care of the compressive strains as well as the shearing strains in the body from the center to the supports. Prac-

tice soon showed that concrete alone was not sufficient to take care of these last strains, as numerous cracks would make their appearance long before the reinforcement or even the extreme upper fibers in the concrete would be anywhere strained to their working capacity. Mr. Hennebique was the first one to introduce his system of stirrups to take care of the shearing strains. His disposition of the reinforcement in concrete beams is now generally adopted as standard, filling well all the needs. I give below a small sketch showing the general arrangement.



Concrete-steel beams generally have a rectangular section. The reinforcement consists of an even number of plain or deformed rods imbedded in the lower portions of the beam. All rods run parallel for a distance equal to about one-third the length of the span in the center. Half of them keep the lower edge the full end of the beam, and the other half reach to the corresponding position in the upper part of the beam over the supports, following the lines of maximum moments in a fixed end beam. A number of stirrups run vertically in the Hennebique system and at different inclinations in some other systems. These stirrups are generally some small-sized rods or wire, all of the same section. They are spaced closer as the shearing strains increase from center to support. The amount of steel reinforcement varies from 0.75 to $1\frac{1}{2}$ per cent. of the total sections of the beam, according to conditions.

The construction of pillars or columns was then only a matter of course. The reinforcement consisted of rods, generally plain, set vertically near the outer portions of the columns and tied together at regular intervals by small rods or flat bars of iron, varying with the loads. The reinforcement amounts to 1 to 2 per cent. of the sections of the column, according to conditions.

I may also say that the steel may be stressed to 16,000 pounds per square inch and a 1-2-4 concrete of good material may be strained to 700 pounds per square inch after a lapse of 6 months; these figures cannot be used for all cases, but only when materials used and working conditions justify it. The concrete is not figured

to take tensile strains except in some certain cases when it cannot act otherwise.

We now have the requisites for nearly all kinds of structures—the slab, the beam and the columns. The rest need be but curtain walls and partitions, also susceptible of the same treatment.

We have seen the evolution of concrete-steel from a flowerpot to a complete rigid, homogeneous frame. The theory has closely followed practice (a seemingly reverse order of things, but actually so), and we are now in possession, from theory and some empiric data, of a fair knowledge of the internal work of concrete-steel. I will not enter into a description of the theory or theories, as they are readily accessible; I will confine myself to a few words on some of the recent applications of concrete-steel in the United States and of the advantages of this new system of construction.

While in Europe the application of concrete-steel embraces nearly all constructions in the domain of the civil engineer and the architect, the adaptation of this method in the United States has been rather slow. It is only within the last few years that concrete-steel work of any magnitude has been constructed.

The advantages that may be claimed for concrete-steel construction are many. Among them can be mentioned the facility for obtaining the materials almost anywhere, the rapidity of erection, the reduction of skilled labor to a minimum; its economy, giving practically a structure having the strength and durability of masonry without its bulk and with the elasticity of steel, and at a cost greatly below the two; its imperviousness when properly treated; its great fire-resisting quality, as I will show later; the fact that both of the materials have practically the same coefficient of expansion; that they will not tend to slip away, but will work together; that the steel once imbedded in the beton will have a complete and permanent protection from the elements which is hardly obtainable in other systems. All of these advantages ought to give concrete-steel a more prominent place among the other systems of construction by engineers and architects. The movement is now forging ahead in the Eastern States. It will not be long before we will be following out here in the West, and in a few years I firmly believe the United States will be ahead of Europe in the application of concrete-steel to all kinds of structures.

Among the recent and most prominent works in the last few years I will cite only a few, as follows:

A 16-story office building in Cincinnati, built entirely on the Ransome system, 50 x 100 x 210 feet high (as high as our "Call" building), having concrete-steel beams of 16 and 33 feet spans; floor

panels, 16 x 33 feet, and columns 12 x 12 inches to 36 x 36 inches. The height from floor to floor in the upper stories was 12 feet 6 inches. This construction permitted a saving of 1 foot in the height per floor on account of the shallow floors, which is quite an item in a 16-story building. The facing of this building consisted of a veneer of marble 4½ inches thick for the first and second stories and 4½ inches of glazed brick for the remaining stories, with terra-cotta cornices and trimmings, showing that the use of concrete-steel does not interfere with the architectural effect that may be desired. Another point—the rate of erection was 2½ stories per month for the concrete work.

A court house for Nassau County, Long Island, N. Y. A monolithic concrete-steel building, 176 x 37 feet in the main part, with an extension of 60 x 52 feet; the building is 2 stories high, with a dome 25 feet in diameter rising 62 feet above the roof. The foundations, walls, columns, roof, dome and ceiling are all of concrete-steel; the floor is made to stand a load of 150 pounds per square foot. This building is also built on the Ransome system.

The beautiful highway bridge at Topeka, on the Kansas River, erected by Mr. Edwin Thatcher. This is one of the most important pieces of work in concrete-steel in the world, consisting of 5 arches of 125, 110 and 97½ feet respectively, built on the Melan system. It has already withstood two floods that have destroyed nearly all other steel and frame bridges in the neighborhood.

The great Miami River highway bridge at Dayton, Ohio, 56½ feet wide and 558 feet long, consisting of 7 three-centered arch spans, designed also on the Melan system by Mr. Edwin Thatcher. It is erected for a floor load of 150 pounds per square foot and a 40-ton electric car on each car track. The bid for concrete-steel was $140,000 for this work, and was lower than any other bid for a steel truss bridge.

A factory for Kelley & Jones, at Greensburg, Pa., 60 x 300 feet. It is a 4-story building, constructed entirely of concrete-steel, on the Ransome system.

Another factory and warehouse for the Central Felt and Paper Company, of Long Island, N. Y., 112 x 312 feet. This building rests on a pile foundation, and was first designed for wood construction, but the owners changed to concrete-steel, and the cost did not exceed 15 per cent. more than the wooden construction. This building is remarkable for the fact that it contains concrete-steel beams or girders 52 feet clear span—a rather long one, indeed—and these beams have to support the roof with a water tank on top of it. The dimensions of the girders are 52 feet long, 30 inches

deep, 15-inches wide, and have nine $1\frac{3}{8}$-inch rods for reinforcement at the bottom and six $1\frac{5}{16}$-inch rods at the top, the stirrups being only $\frac{3}{16}$-inch wire.

In a hall of music at Cincinnati, by L. Mensch, built on the Hennebique system, there are girders of 61 feet span under the balcony.

A water tower or standpipe near Boston, for the United States Government, built on the Hennebique system, is 20 feet in diameter and 50 feet high; the thickness of the wall at the base is only $6\frac{1}{4}$ inches, with 1 inch of Portland cement plaster, making this structure completely water-tight. Again, in this case, the bid was 30 per cent. lower than any other.

There are two 45-foot spans for a highway bridge at Santa Monica, erected by Luten on a system of his own, showing what could be done for small spans in many places in California, which are now spanned with steel or wooden structures which need constant repair and attention (which is seldom given to them by our city and county supervisors); while a concrete-steel bridge would cost but very little more in the beginning and would not require any attention whatever.

Concrete-steel for culverts and bridges in railroad work are coming into use more and more every day, and their cost (even for large spans) compares very favorably with masonry and steel spans, the latter having to be changed every generation due to the increase in rolling stock.

The Roxborough filters for the Philadelphia filter system are composed of posts and groined arches, reinforced with expanded metal and corrugated bars.

There is a chimney in Los Angeles for the Pacific Electric Railway Company which is 180 feet high, made of 2 concentric rings, one 15 feet 2 inches and the other 11 feet in diameter, the outer shell being only 9, 6 and 5 inches at different heights; the inner shell is 5 to 4 inches—all built on the Ransome system.

There is a pile foundation for the Hallenbeck Building, New York, which dispensed with the use of costly caissons and piers; the piles are 12 inches square, 28 feet long, and the reinforcement consisted of four $1\frac{7}{16}$-inch rods. Each pile was to take a load of 80,000 pounds. This was built on the Hennebique system.

The Stadium at Harvard, with a seating capacity of 40,000 (resembling in a way the Roman Coliseum), is 570 x 420 feet, the outside wall being 53 feet high. This building was designed by Charles F. McKim.

There is also the intercepting sewer for Cleveland, Ohio, 14 feet in diameter and 3½ miles long, built on the Parmley patent.

The coal storage bin for the Lowell Gas Light Company, Lowell, Mass., with a capacity of 25,000 tons.

A storage bin for cement for the Illinois Steel Company, consisting of 4 bins, 25 feet in diameter and 54 feet high, with a capacity of 25,000 barrels, built on the Monier system.

A grain elevator in Ontario, with a capacity of 500,000 bushels, each tank being 30 feet in diameter and 70 feet high.

An example of the resisting qualities of concrete-steel against fire may be cited. In Baltimore there was an old building in which the outside walls were of brick and the inner frame of the ordinary construction of wooden posts, wooden beams and wooden floors. Before the fire this building was entirely remodeled and the inside wooden frame was replaced by concrete-steel frame; that is, all of the columns, beams and floors were changed, only the brick wall being retained. The terrible fire came; everything in the block where this building stood was completely gutted. After the fire there was nothing left but the concrete-steel frame, which stood there mute, but more impressive and eloquent than any words can express. Two weeks after the fire the floors in this building were loaded with 300 pounds to the square foot, and stood this test, showing that the fire had not in any way impaired the strength of the columns, beams and floors.

In all of the above I have shown the actual application of various systems of concrete-steel to a number of different structures, among which are office buildings, factories, warehouses, chimneys, coal and ore bins, grain elevators, filters, sewers, court houses, theaters, hospitals, schools, water towers, bridges, railroad culverts, stairs, etc.

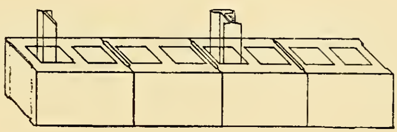
I could continue this list, but it would only be a repetition of itself. I hope that this paper will awaken in the members of this Society and in engineers and architects at large, a desire to familiarize themselves with this new construction, and that it may become of universal benefit.

A NEW METHOD OF BUILDING CONSTRUCTION.

By S. Giletti, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 27, 1904.*]

The writer herewith intends to present to the Technical Society some recent improvements in the construction of walls, partitions and floors for business blocks, residences and other structures hitherto constructed of stone or steel. Ordinarily, in the erection of such structures, the steel skeleton frame is first reared, then the stone, brick or terra cotta are placed around this frame. The plan now to be described provides a method of construction in which the walls are built first, raising them story by story, and, as each story is raised, the metallic frame is inserted in flues left open for this purpose. The flues, of concrete hollow blocks, where the metallic column is placed as designated, are filled in, binding the whole into one rigid and indestructible body.

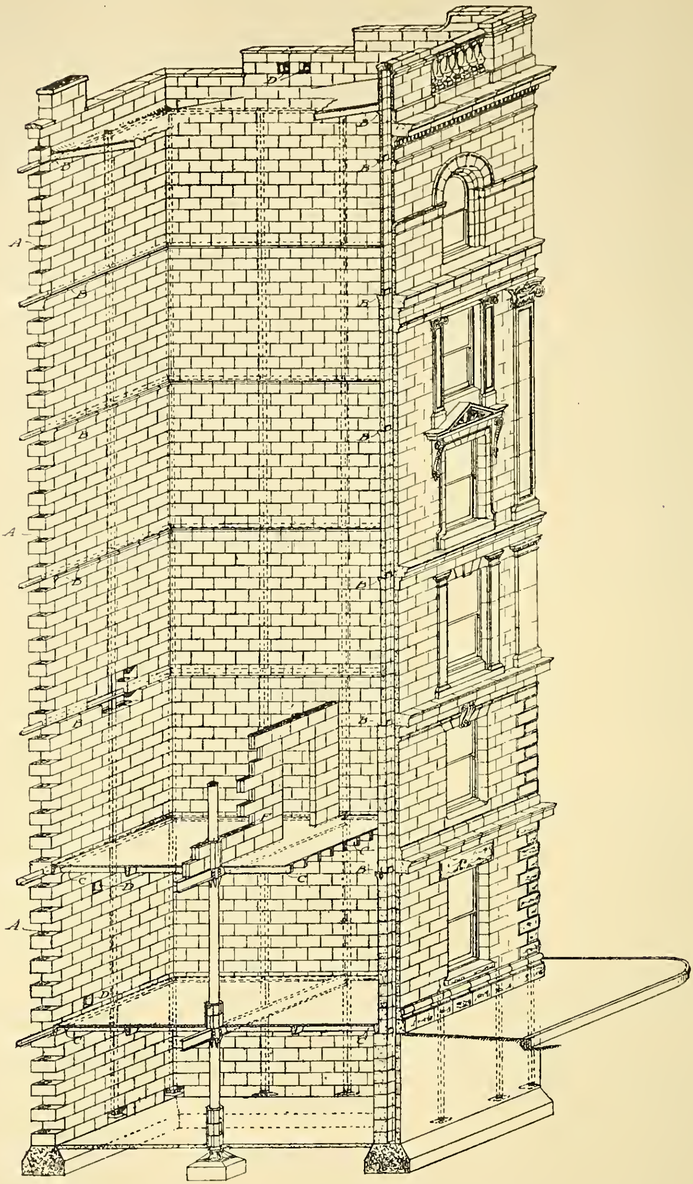


In the system commonly used, where the steel frame is first erected, the metal must be painted in order to protect it from rusting; then, when stone or brick is built around it, the paint forms a most effectual means of keeping the stone or brick and the metal apart. In our case, however, the concrete wall is first built up, and then the parts of the steel frame are inserted in the flues. As each piece can be cleaned just before its insertion, it is entirely free from rust. As the flue is then filled in with concrete, the latter unites with the metal, protecting it from rust for an indefinite period; and, because their coefficients of expansion are equal, the two parts form really one mass.

Usually the steel frame of a building is inaccessible after its completion, and deterioration cannot be observed. In our case no anxiety in this regard need be felt, for the steel is preserved in the best possible manner.

The outside surface is made in imitation of sandstone, or it may be made to imitate any kind of granite, or even brick.

* Manuscript received June 20, 1904.—Secretary, Ass'n of Eng. Socs.



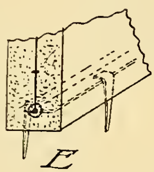
Through the hollow artificial stone blocks flues are provided, about 8 inches, more or less, square; these flues start from the foundation of the building and continue to the top of the main cornice in vertical lines. The dimensions of the hollow blocks may vary, according to the size and capacity of the structure. The belt courses, cornices and ornaments of the outside of the building may be made in

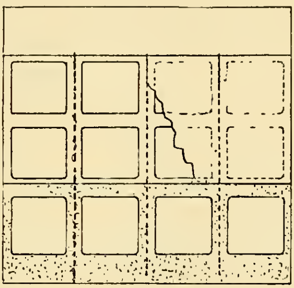
part of hollow blocks, cast in the same mold, so as to make a perfectly sound stone.

The surfaces of the hollow blocks, forming the interior walls of the structure, are made rough enough to form a perfect key to receive and hold the plaster, thus avoiding the necessity of the use of any kind of lath.

Upon the last or upper course of each story there is provided a projection (B) from the interior vertical line of the walls. This projection provides a proper bearing for steel girders or wooden joists.

The hollow blocks mentioned, which form the walls of the building, rest upon a solid foundation made of concrete, and through the interior wall of the lower courses of blocks there are provided openings, from 5 to 8 inches square, so as to afford ventilation or to give access to heaters, thus enabling the occupants, by a proper regula-





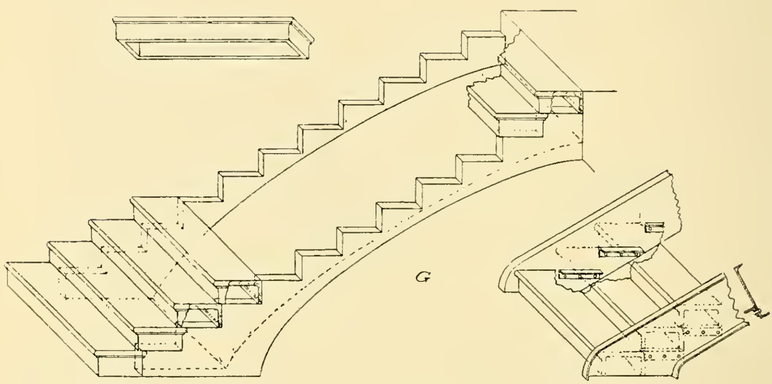
tion of the ventilators, to keep a current of cool air running through the exterior walls of the building during the heated days of summer, and also to convey heated air from the furnaces to any part of the structure in winter, by carrying the furnace conduits to such flues as connect with the various parts of the structures which it is desired to heat. Other flues may be used as conduits for plumbing pipes and electric wires, also for speaking tubes.

It will likewise be observed that the hollow flues afford an opportunity for placing stoves or other heating apparatus in any of the rooms of the building at the will of the occupant. This will be found particularly desirable in the kitchen and laundry. The tops of the flues are covered, at the cornice or fire walls, with solid stone, except, of course, in the case of chimneys or ventilators. This stone can be pierced or closed at will, so as to change the flues if desired.

The fireproof arched floors consist of concrete beams, E, reinforced with steel plates and forming small arches, as shown on the plans. No. I-beams or girders are needed for spans up to 30 feet

from wall to wall, or from I-beam to wall. This floor will carry 316 pounds to the square foot. The arches weigh about 40 pounds per square foot. With this system there is no need for any iron frame to support the iron lath for the ceiling, as seen from plans and section, E. By making the sheet steel beams heavier and placing the girders closer together any desired load may be carried.

The interior partitions are fireproof; they are 4 inches, more or less, in thickness, including the plaster, and they are made of cement, cinders and galvanized wires. The wire are ¼ inch in thickness, and run vertically from floor to ceiling, from 12 to 24 inches apart, according to the height of the story and to the strength required. The wires are to be placed opposite to one another, on each side of the partition, and a small wire is to tie both galvanized wires in every course of cement and cinder tile, so as to form a perfectly rigid



and solid body. After the partitions are built up, they may be plastered on both sides in the usual way. The weight of partition, including tile, plaster and wire, is about 22 pounds per square foot.

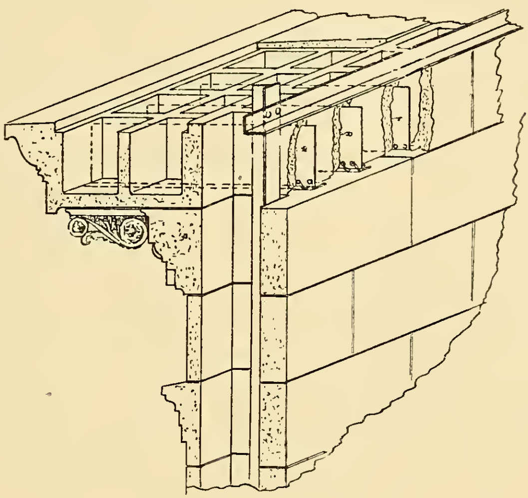
The stairs are constructed upon the same principle as the arches, as per plans and section, and the material is cement and marble composite; the treads and risers form one solid piece and the interior of the step is hollow, its weight being about 35 pounds per lineal foot. The steps can be laid on iron, wood or concrete arches as strings. The latter is preferable, is more fireproof and gives more satisfaction in shape and economy.

In order that builders may better appreciate the advantages of this method of construction, it is necessary to describe briefly the manner in which the hollow blocks of artificial stone are made.

A mold is used, with a core, having its walls connected by a bar extending centrally through the core, whereby the size of the

core may be increased or reduced, according as the links are operated, while inserting the core into the mold or withdrawing it therefrom. When it is desired to remove the core, the simple act of the operator taking hold of the handle of the bar and giving a moderate pull causes the links to turn on their pivots, freeing the casing from the surrounding stone or cement, and the core is withdrawn through a hole on one side of the mold, leaving the still green block entirely uninjured. It is not necessary to wait for the block to dry. The core is unaffected by moisture, and is ready for any design, style or size of hollow artificial stone or tile.

Hitherto it has been impossible to obtain a perfectly sound artificial stone block. This is due to the fact that, while filling the



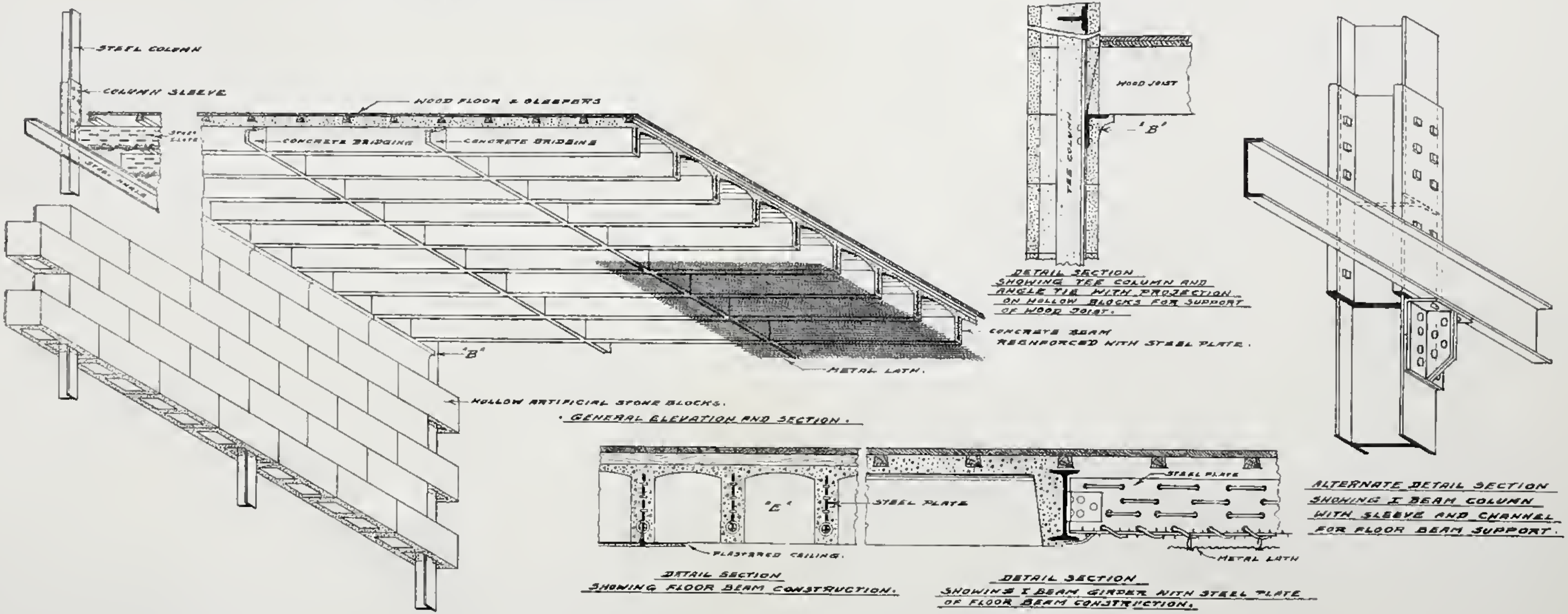
mold or plaster cast hitherto universally in use, the moisture contained in the cement or concrete would get into the apparatus or mold, and, becoming imprisoned in the block, would cause the stone to swell after its release from the mold. This swelling necessarily produces a crack. The crack, however, does not manifest itself until the block begins to dry or even after the block has been actually set in the building. Concrete workers have not as yet been able to overcome this unfortunate condition of affairs except by the use of the core above described. By use of this, however, blocks of stone, either hollow or solid, may be manufactured, turned out and preserved as free from cracks as native stone. This great advantage now renders possible buildings of artificial stone as solid and durable as granite.

The cost of constructing walls of common brick on the outside

and lathing within, and having terra-cotta chimney flues with heater and ventilator conduits, according to the old style, averages in San Francisco, Cal., 55 cents per cubic foot. A brick building, with sandstone front, constructed in like manner, would average 90 cents per cubic foot. If constructed with granite front it would average $1.25 per cubic foot. These figures place the construction of such buildings practically beyond the means of the middle class and make them possible only to the wealthy. Even for such people the cost is so great as to reduce materially the rate of interest to be derived from their use.

The method herein described, as heretofore stated, does away not only with lathing, but also with furring, upon which the former must be put; it also does away with the terra-cotta or brick chimneys, and with heating pipes, ventilators and conduits. In addition to this, it obviates the necessity of the exterior plastering and painting, and much labor is saved in plumbing work throughout the building. These savings so reduce the cost that buildings may now be constructed of even greater durability than formerly and vastly more artistic in appearance. Much space is saved in the interior on account of the small thickness of walls, as the buildings constructed according to this method have walls of about one-half the thickness of those of the old-style brick and stone construction, and the cost is limited to 25 cents per cubic foot at the factory, or 42 cents placed in position. Not only is this great saving effected, but the building so constructed will be far more comfortable to the occupant as well as more healthful. In such buildings dampness is obviated, since no moisture can ever penetrate the hollow cement blocks. A better system of ventilation is possible and a more even temperature within can be maintained. It will readily be seen that this method of construction places owners in such an advantageous position as to preclude competition, and assures profits far in excess of ordinary business undertakings. To-day every improvement in construction is eagerly adopted, and this is so manifestly an advance in building practice, to say nothing of the saving effected, that it is worthy of every consideration on the part of those who are interested in building methods.

S. GILETTI PATENT SKELETON STEEL FRAME, HOLLOW ARTIFICIAL STONE BLOCKS AND FIRE PROOF FLOOR CONSTRUCTION



MANUFACTURE AND TESTING OF PORTLAND CEMENT.

By C. J. Wheeler, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 28, 1904.]

The practice of using limes in binding stone, brick, and other building materials is one of great antiquity. The exact date of the discovery that calcined marble, or other pure limestone, slacked with water, would make a good cementing material is not known. The ruins of the Phœnicians and Egyptians show clearly that they were acquainted with its properties. The Romans, the greatest architects of the ancient world, were well acquainted with the use of limes, as also with certain methods of improving fat or pure limes in order to impart to them cementitious and hydraulic properties.

Vitruvius and Pliny describe methods for the manufacture and use of limes, and also certain additions to be made to them in order to give hydraulic properties.

The ancients believed and worked upon the principle that the harder the rock before burning, the better the hydraulic properties of the resulting product. This theory held sway from the time of the Romans up to 1776, in which year John Smeaton, an English engineer, in selecting a hydraulic material for the foundation of the Eddystone Lighthouse, made the discovery that the hydraulic properties of a lime depended not upon the hardness of the original limestone, but upon its clay content. This was the first real advancement which had been made in over 2000 years. From this time until 1824 a large number of patents were taken out in England on materials which resembled Portland cement and had some of its properties, but were called by different names. In 1824 Joseph Aspdin, a Leeds bricklayer, patented a process for the mixing and burning of lime and clay, and, in consequence of its fancied resemblance in color and in texture to the oolitic limestone from the island of Portland, which was then used in large quantities as a building stone, called it Portland cement.

For 50 years after Aspdin's first experiment very little advancement was made. A number of mills were operated in England, Belgium and Germany, but a very indifferent article was produced. Between the years 1870 and 1880 the attention of scientific men was called to the industry through the demand for a better hydraulic material in engineering work, and, while our knowledge at the present day is still limited in regard to the chemical reactions which

take place in the process of manufacture and setting, we still have made wonderful progress in the science.

The first Portland cement manufactured in the United States was made by the Copley Cement Company, at Copley, Pa., in 1875. Their initial output was very small, being about 2000 barrels the first year. From 1875 the industry has gradually spread until in 1903 the United States produced about 17,230,644 barrels.

The process of manufacture was formerly divided into 3 distinct systems—the wet, semiwet and dry. These have been so modified that at the present time we have only 2—the wet and the dry. The wet system is used very extensively in the marl district of this country and the chalk and mud districts of England. In other parts of the world the dry process is used almost exclusively. It will not be necessary to deal with each of these systems in detail, as they both aim at the same final result—the thorough incorporation of the lime material with the required proportion of clay material and the finest subdivision possible of the resulting product.

One of the most important if not the most essential point which a cement manufacturer has to deal with, is the fineness of the grind of his compound or raw material. No matter how well a cement mixture may be compounded and burnt or how fine the resulting cement clinker may be ground, if the raw compound is not properly ground, the finished cement will be valueless.

I have found that where this material is coarser than 95 per cent. passing a 100 mesh sieve in mills using pure limestone and low lime-carrying clays, the resulting cement gives very unsatisfactory results. In mills using a high lime-carrying clay much coarser grinding is allowable. But this rule will always apply—the finer the compound is ground, the better the resulting cement will be.

After the compound is mixed and ground, its future treatment depends upon the type of kiln in which it is to be burnt. If any of the forms of upright, or, as they are sometimes called, standing kilns, are to be used, the compound or slurry must be either dried, if the wet method has been used, or dampened, if the dry method was used, to such a consistency as will allow it to be molded into bricks or formed into cakes. The water is then all evaporated, either by the heat of the sun or by some suitable form of drier, in which condition the so-called compound is ready to be loaded into the kilns.

If the rotary system is to be used, the wet slurry or dried compound is ready to be introduced at once into the kiln without further treatment.

The oldest form of kilns in use to-day are the ordinary open or

bottle form. They take the name of bottle kilns from their shape, which somewhat resembles a bottle, narrow at the top and bottom and bulging in the center. These kilns are built in different sizes from 20 to 50 tons capacity, the ones most frequently met with giving about 35 tons per charge. Hard coke is most generally used as a fuel in this class of kilns. Both hard and soft coal have been used, but with indifferent success.

To charge a furnace of this kind a layer of wood is first placed on the grate bars, then a layer of coke or coal; whichever is used, over this a layer of compound which has been formed into bricks or cakes. From this point the furnace is filled with alternate layers of fuel and compound until the working room of the furnace is full. The amount of fuel to be used must be determined by experience, it being impossible to lay down any set rules, as any small change in the composition of the compound makes a difference in the amount of fuel required. The proper loading of kilns of this kind is an art in itself, and is always undertaken by experienced men. All of the kilns of this class will be found to have little peculiarities of their own; a slight difference in draught, for example, sometimes spoiling a whole kiln of cement. In loading kilns of this type great care must be exercised that the draught is not choked or made too free. If it is choked, it will be found impossible to get the required heat; and if it is too free, too much heat will be developed in some places and not enough in others. After firing one of these kilns, it is usual to allow it to burn and cool about 6 days before drawing. The material will be found well burnt near the bottom, lighter burnt toward the top and usually a layer of underburnt on top. The product has to be picked by hand, the well burnt going to the grinding department, the underburnt and lighter burnt returned to the kilns for reburning.

A number of modifications of this kiln have been made in late years, chambers having been added in which to dry the slurry by utilizing the hot gases which escape from the top of the stack. Arrangements have also been made to make a continuous kiln of this class by adding fuel and compound as the charge is burnt and drawn off from the bottom. But experience has taught that it is not an economical process, either in the use of fuel or labor, and it is gradually going out of service.

Another class of kilns, of which the Dietzsch and Schoffer are the only ones in use in this country, employ an arrangement whereby the waste heat is used to bring the dried compound to a red heat before it is drawn into the burning part of the furnace.

They consist of 3 chambers, one over the other, arranged in

such a manner that the lower contains burnt clinker which is cooling; the middle, the compound under process of burning, and the upper, the raw compound which is being heated. Coal is used in this type of kilns as a fuel. The process is continuous and the result obtained very good.

Until about 15 years ago in this country and about 2 years ago in Germany the above class of kilns were the principal ones in use.

In the latter part of the eighties, Mr. F. Ransom brought out a special furnace for calcining cement with gaseous fuel, which consisted of a slowly rotating cylinder lined with fire brick and set at a slight angle from the horizontal. The fuel was introduced at the lower end and the dried slurry in small pieces at the upper end. In consequence of the angle of inclination, the dried material gradually worked its way down to the flame, became clinkered and dropped out of the lower end. The interior of Ransom's furnace was filled with projections of fire brick which carried the material up as the furnace revolved and dropped it through the flame, in this way giving the flame more surface to act upon, consequently producing a more even calcination than when large masses were exposed to the heating agent as in the standing kilns. This kiln was used in England a short time, but was not a success, as, in the first place a lining which would stand the fluxing action of the cement mixture could not be obtained. The cement which was made by this kiln was so abnormally quick setting that it was valueless.

From these experiments of Ransom's, however, the rotary kiln process has developed very rapidly, especially in this country, until now it is used almost universally.

In Europe its introduction has not been so rapid. In 1893 there were only 10 in use, but the success with which they have met is causing a gradual replacement of the old standing kilns. The process as we know it in the United States is almost identical with Ransom's. The kilns consist of a moving cylinder, generally 60 feet long and 72 inches in diameter, set at an inclination of ½ inch to the foot. The upper end extends into a stack base, through which is run a conveying appliance to introduce the raw compound. The lower end is extended into a hood, through which is introduced the fuel, either powdered coal, oil or natural gas. The cylinder is lined throughout its entire length with a heavy basic brick 9 inches thick. Over the cylinder at the rear end, when the dry method is used, a large storage bin for the raw compound is placed. If the wet method is used, tanks are placed back of the furnace for holding the slurry, which is introduced through the rear housing by means of pumps. The kilns are usually driven from a variable speed machine.

This regulator gives the operator full control of the speed of his furnace and the amount of compound which is introduced, and this, with the regulation of his oil, gives him full control of the hardness of the burn. The regulator gives a variation of from 15 to 75 revolutions per hour.

The method of starting a rotary kiln is very simple; a small wood fire is built in the lower end of the cylinder and the fuel turned on. The cylinder is revolved at a very low speed, and the compound, feeding into it at the upper end, gravitates toward the burning zone where the clinkering begins and continues as long as the heat is sufficiently high. The burning zone is about 10 feet from the front of the furnace, and usually has a temperature of about 3000° F.

The clinker as it comes from the standing kiln will always be found to be more or less mixed with over- or underburnt material. This must be carefully separated, usually by hand, before the clinker is ground. From a rotary system, owing to the control which the burner has over his compound and fuel, the resulting product is always well burnt. The consequence is that the cement ground from this process is always higher in tensile strength and more even in color than that from any other system; and, owing to its freedom from underburnt material which always contains free lime, it is more liable to be sound and constant in volume. When the clinker by itself is freshly ground it is usually quick setting. To regulate the setting time the ground cement must either be allowed to age for some length of time or some aging material added to it to hasten the action. The material which is most commonly used is gypsum, either in its crude state or as plaster of Paris.

There are a number of theories explaining the action of this material upon cement, but we are not well enough acquainted with any of them to state which of them is correct. About the only knowledge we have of the action is that we can take a cement which has an initial set of 5 minutes, and, by the addition of a very small percentage of gypsum, less than 2 per cent. of calcium sulphate, increase the initial set to 2 or 3 hours.

The grinding of cement clinker is one of the most important operations in the manufacture. A few years ago 90 per cent. on a 50 mesh and 80 per cent. on a 76 mesh was considered a well-ground cement. At the present time 90 per cent. on a 100 mesh and 75 per cent. on a 200 mesh is thought to give the best results, although some engineers require finer grinding than this, claiming that the finer a cement is ground, the further it will go in work and the stronger concrete it will give. This is true up to a certain point.

A cement can, however, be ground so fine that it will become very quick setting, in which condition it is valueless.

To illustrate this, a sample of cement 1 year old was taken:

Fineness:

100 mesh, 93 per cent. passed.
200 mesh, 74 per cent. passed.
Initial set, 2 hours 35 minutes.
Final set, 5 hours 30 minutes.

A sample of this same cement ground by hand to the fineness:

100 mesh, 98 per cent. passed.
200 mesh, 90 per cent. passed.
Initial set, 1 hour 30 minutes.
Final set, 4 hours.

Another sample of this same cement ground to fineness:

100 mesh, 100 per cent. passed.
200 mesh, 100 per cent. passed.
Initial set, 5 minutes.
Final set, 15 minutes.

This same experiment has been tried on other cement, both foreign and domestic, and in every case the same results have been obtained.

The reason a fine cement sets quicker than a coarser one is found in the Le Chatelier theory for the setting of a cement. According to this theory, the water dissolves out the more soluble parts of the powder, forming a supersaturated solution, which subsequently deposits crystals and gradually forms a solid mass. Obviously, therefore, the finer a cement is ground, the more rapidly the water can act upon the particles and the quicker setting it becomes.

Another factor which plays an important part in the quality of a cement in regard both to the tensile strength and set is the method used in grinding. By this I mean whether the clinker is crushed and screened and the coarser particles recrushed, or whether the cement is all ground fine at one operation. To illustrate this, I have introduced several sets of tests which I had occasion to make a number of years ago in an Eastern mill where several different methods were used for grinding.

The clinker from which the several samples were ground was all taken from the same heap, and was as near uniform as it was possible to obtain:

Experiment No. 1, Ground on under runner millstones and Columbia separator.

Experiment No. 2, Ground on edge runners.

Experiment No. 3, Griffin mills.

Experiment No. 4, Ball and tube mill.

Experiment No. 1, Fineness:
100 mesh, 92 per cent. passed.
200 mesh, 68 per cent. passed.
Initial set, 3 hours 25 minutes.
Final set, 7 hours.
Soundness, not perfect.
Constancy of volume, not constant.

TENSILE STRENGTH.

Neat.	Sand 3, Cement 1.
3 days, 295 pounds.	85 pounds.
7 days, 590 pounds.	185 pounds.
28 days, 680 pounds.	290 pounds.
6 months, 680 pounds.	280 pounds.

Experiment No. 2, Fineness:
100 mesh, 92½ per cent.
200 mesh, 65 per cent.
Initial set, 3 hours 15 minutes.
Final set, 6 hours 30 minutes.
Soundness, not perfect.
Constancy of volume, not constant.

TENSILE STRENGTH.

Neat.	Sand 3, Cement 1.
3 days, 310 pounds.	85 pounds.
7 days, 625 pounds.	195 pounds.
28 days, 715 pounds.	300 pounds.
6 months, 710 pounds.	315 pounds.

Experiment No. 3, Fineness:
100 mesh, 93 per cent.
200 mesh, 74 per cent.
Initial set, 2 hours 25 minutes.
Final set, 5 hours 30 minutes.
Soundness, sound and perfect.
Constancy of volume, constant.

TENSILE STRENGTH.

Neat.	Sand 3, Cement 1.
3 days, 320 pounds.	110 pounds.
7 days, 635 pounds.	225 pounds.
28 days, 740 pounds.	335 pounds.
6 months, 810 pounds.	380 pounds.

Experiment No. 4, Fineness:
100 mesh, 93 per cent.
200 mesh, 75 per cent.
Initial set, 2 hours 15 minutes.
Final set, 5 hours 25 minutes.
Soundness, sound and perfect.
Constancy of volume, constant.

Tensile Strength.

Neat.	Sand 3, Cement 1.
3 days, 315 pounds.	125 pounds.
7 days, 640 pounds.	230 pounds.
28 days, 725 pounds.	345 pounds.
6 months, 845 pounds.	375 pounds.

Pat tests in cold water on Nos. 1 and 2 were very unsatisfactory, being warped, checked and cracked at the end of 6 months. Nos. 3 and 4 pats were perfect and sound on glass at the end of 1 year. This cement contained 2 per cent. of added gypsum. Under the microscope the particles of the cement from the different mills were as different as it was possible to conceive them. In Nos. 1 and 2 they had every appearance of the original clinker, while in Nos. 3 and 4 an entirely different appearance was observed. The particles had lost their clinker-like appearance and had taken on that of a dark-colored flour. These cements were held about 4 months and again sampled. Practically the same results were obtained as in the first case.

The only conclusion we can draw from the above tests is that the method used in flouring a cement clinker has a very marked influence on the resulting cement.

After the cement is ground and stored in the aging bins there comes from the engineer's or consumer's point of view another very important operation; this is its testing, to determine whether it is fit to go into work.

In Germany, France, and other European countries the Government has taken the testing of Portland cement under its protecting wing and formulated set rules and tests which it must pass before being used. In England and the United States every engineer and consumer has his own ideas about the way a cement should be tested, and as the ideas of these gentlemen usually vary considerably, it is a difficult problem for the manufacturer to formulate rules for testing which will satisfy all of them. The rules which we have adopted at our own works and which are in general use in all the larger mills in this country are those laid down by the German Government. They are slightly modified as to the fineness and soundness tests, but in the main they are the same.

They consist of tests for:

Soundness—freedom from destructive agencies within itself.
Fineness of grinding.
Strength—cohesive and adhesive.
Setting properties.
Weight and specific gravity.
Chemical composition.

The above tests properly carried out will give a fairly good criterion of what the future action of the cement will be.

Care, however, must be taken not to draw erroneous conclusions from any single test or from the whole list of tests at any one time. It is the aggregate of the whole, observed at different periods for a comparatively long time (30 or 60 days), which gives the best results.

SOUNDNESS.

The soundness should always come first in the list of tests. No matter what qualities a cement may possess, such as being finely ground, giving high tensile strength at short periods, etc., if it is not sound it will eventually expand, disintegrate and become absolutely valueless, or worse than valueless, as a binding material. The first method used in determining soundness, and the one which is used as a base for all accelerated tests to-day, is to make a thin pat upon a glass plate, and, after the final set has taken place, to immerse it in cold water (60° to 80° F.). If at the end of 30 or 60 days, or any other longer period, it develops no checks, cracks or alterations from its original form, it is considered sound. There have been a number of accelerated tests proposed and used in different parts of this country to obtain this same end.

Henry Faija subjected a freshly gauged pat to a moist heat of 100° to 105° F. for 6 or 7 hours, or until set, and then immersed it in water at 115° to 120° F. for the rest of the 24 hours. If the pat was firm and solid upon the glass, the soundness was said to be perfect.

Michaelis subjected a pat of set cement to water heated to 212° F. for a period of 2 hours. If at the end of this time the cement was solid and firm upon the glass, the soundness was perfect.

A number of other tests on these same lines have been proposed, and are used with more or less success in different localities.

The fineness of a cement is ascertained by sifting a given weight through a sieve composed of brass wire gauze having a given number of meshes to the square inch. In the United States, sieves of 100 mesh (10,000 mesh per square inch) and No. 200 mesh sieve (40,000 mesh per square inch) are the ones in common use. These sieves are considered standard when the wire is one-half the size of the opening.

For practical purposes it will be found sufficient to take 100 grams, and, after sifting until no further appreciable quantities can be gotten through, the residue is weighed. The weight in grams

will represent the percentage of residue retained by the sieve used. The amount passing the sieve is the one usually reported, *i. e.,* if the cement is said to be 90 per cent. fine, it signifies that 90 per cent. has passed the sieve used, 10 per cent. being retained.

TENSILE STRENGTH.

Too much importance as a usual thing is placed upon the tensile strength of the neat cement. Any of our cement, ordinarily, is strong enough at some period in the time of testing to satisfy almost any specification. It is rather the rate of increase to which the value should be attached. A cement that develops a moderate strength at the end of 7 days and shows an increase of 25 per cent. at 28 days, is better than one showing a comparatively high strength at the end of 7 days and only 5 or 10 per cent. increase at the end of 28 days.

In making briquettes much depends upon the skill of the operator. Each operator has a personal error which should always be taken into consideration when comparing results. The exact rules for making briquettes should be formulated and no variation allowed except where the cement requires them, and these should always be noted in the report upon that cement. Briquettes are usually made in lots of 10 or 20 at a time. The cement is weighed and the amount of water is added which will make a plastic mortar. It must then be thoroughly worked with a trowel until the water is thoroughly incorporated with the cement. The molds are filled either by pressure with the thumbs or by the use of a small rammer and struck off with the trowel.

The sand briquettes, which are much more important than the neat, are made by mixing 3 parts of standard sand and 1 part of cement dry, and then adding from 9 to 10 per cent. water and again mixing. In placing the sand mixture in the molds care must be used to obtain a briquette of a standard weight. If the mixture is rammed too hard, too high a tensile strength will be obtained, and if not rammed hard enough it will be too low. After making, the briquettes are allowed to lie 24 hours in moist air and are then placed in the water (60° to 80° F.) until tested. The results are usually noted at 3 different periods—3, 7 and 28 days. For most purposes this is sufficient, but where great care is necessary, 2 months, 6 months and 1 year are sometimes required.

A number of machines have been patented for the making of briquettes, but they are not very extensively used in the United States.

SETTING PROPERTIES.

The setting properties of a cement are not of great importance unless they are abnormally quick or slow, except for special work. We divide the setting of a cement into 2 periods, called "initial" and "final" set. The period which elapses between the adding of the water and the moment when the mass loses its fluid condition is called the time of initial set.

In quick-setting cements this is very distinctly marked, while in slow setting it is so gradual as to be scarcely noticeable.

Final set is the time which a cement takes to acquire sufficient hardness to withstand certain pressure without leaving any indentation.

In determining the initial and final set we use what is called Gilmore needles. They consist of 2 needles, one weighing $\frac{1}{4}$ pound and carrying a wire $\frac{1}{12}$ inch in diameter, the other weighing 1 pound and carrying a wire $\frac{1}{24}$ inch in diameter.

When a cement is mixed to a standard paste (with 25 to 30 per cent. of water) and will carry the $\frac{1}{4}$-pound needle, it is said to have taken its initial set; when it will carry the 1-pound needle, it is said to have taken its final set.

SPECIFIC GRAVITY.

The object of ascertaining the specific gravity of a cement is to enable some opinion to be formed of the amount of calcination to which the sample has been subjected, as the harder the burn the greater the specific gravity will be.

CHEMICAL COMPOSITION.

A first-class Portland cement always has a chemical composition within the following limit:

Oxide of calcium	59 to 65	per cent.
Silica	19 to 25	" "
Oxide of iron	2 to 4	" "
Alumina	5 to 9	" "
Oxide of magnesium	0.5	
Sulfuric anhydride	0.2	
Alkalies	0 to 1	" "

THE COMPARATIVE ECONOMY OF VARIOUS TYPES OF HIGHWAY BRIDGES.

By C. B. Wing, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 28, 1904.*]

"A road, once accepted and used as a public highway, must be maintained in condition for safe use until legally abandoned. If a highway crosses a stream, and a bridge is built to provide for such crossing, the structure becomes part of the highway, and must likewise be kept in condition at all times for safe reasonable use, and, if worn out or destroyed by accident, must be replaced."†

The cost of a bridge structure is therefore the annual expenditure necessary to perpetually maintain the same in condition for use, and in general that structure should be built for which such annual expenditure will be a minimum.

In some cases, maintaining a bridge at the least annual cost may involve building a type of structure the first cost of which is greater than the present generation can bond itself to construct. Again, the future needs of a district may be uncertain and the building of a temporary structure justifiable. On the other hand, the wealth and æsthetic development of the community may demand a limited expenditure of public funds for artistic and monumental effect.

Disregarding, however, exceptions to the general rule, the following discussion will be confined to outlining methods for determining, in any given case, the type of bridge structure that will cost the least yearly sum for perpetual maintenance.

Considering the building of a bridge as an investment of funds by the community, provision must be made for interest, sinking fund and operating expenses. Therefore the annual cost of perpetually maintaining a bridge may be assumed to be made up of the following items:

a. Interest on capital invested.
b. Sinking fund.
c. Maintenance.
d. Insurance.

That type of bridge will be most economical for which the annual sum of the above items is the least.

The invested capital is the first cost of the completed structure. In determining the annual interest charge, the rate of interest may

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* Manuscript received June 30, 1904.—Secretary, Ass'n of Eng. Socs.

† Sec. 2715, "Political Code of California."

be assumed to be the ruling rate for bonds of the community, making due allowance in the case of permanent structures for a decrease in such rate in the course of time.*

If the bridge is built of perishable materials, the whole structure will have to be replaced when worn out. To meet this expense provision must be made for a sinking fund which, in the course of the estimated life of the structure, will create a fund sufficient to replace the same when necessary.

Such bridges also require a constant annual expenditure for maintenance, such as repairing floors, painting, etc.

Another item of annual cost not often taken into account in comparing the cost of permanent bridges with those built of perishable material is that of insurance against accidents to the structure itself or the traffic it carries. A worn-out wooden floor frequently gives rise to a suit for damages, and in time of flood a properly designed masonry bridge is much less likely to be destroyed than one built of wood or steel.†

For the purposes of the present discussion highway bridges may be divided into four types:

Type I.—Wooden bridges.
Type II.—Combination bridges.
Type III.—Steel bridges.
Type IV.—Masonry bridges.

To determine the annual cost of perpetually maintaining bridges of the above types, it is necessary to know their first cost, probable life and cost of maintaining in condition for use.

FIRST COST OF STRUCTURE.

The first cost of structures of the above types for any given location can be best determined by actual designs with estimate of cost. In many cases these designs can be submitted for bids and the comparison of costs made after the bids are opened.

LIFE OF STRUCTURES.

A masonry structure well designed and carefully executed may be considered as permanent in character. One writer has said of masonry: "Its first cost should be its only cost. Though superstructures should decay and drift away, though embankments should

* Napa County, Cal., bridge bonds bearing 4 per cent. interest recently sold at par.

† The fact that a masonry bridge withstood the Johnstown flood has led many railways to adopt that type of construction wherever practicable.

crumble and wash out, masonry should stand as one great mass of solid rock, firm and enduring."*

The durability of the other types of structures mentioned varies greatly with their location and the care taken to maintain them. The life of the structure as a whole will usually be much greater than that of its parts; thus the floor of an uncovered wooden bridge may have to be renewed four times and the stringers and floor beams twice before it is necessary to renew the trusses.

The life of the structure as a whole can usually best be made the basis of computing the annual contribution to a sinking fund for replacing the structure when worn out.

The cost of renewals of flooring and stringers may then be charged to maintenance.

The following method may be used for computing the annual cost of replacing a structure when worn out.

Let M = cost of structure to be replaced.
n = life of structure in years.
r = annual rate of interest.
A = annual payment to sinking fund.

If the interest is compounded annually,

$$A = \frac{M r}{(1 + r)^n - 1}$$

Thus the first cost of a structure and its probable life being known, the annual cost for sinking fund can be readily determined.

Sixteen, twenty-four and forty years may be taken as average values of the life, respectively, of unprotected wooden, combination and steel highway bridges.

In any given case careful study should be made of conditions of design or location modifying the above values. For instance, a covered wooden bridge may outlast a steel structure, the painting of which has been neglected.† In fact, it will usually be safe to assume in estimating the life of highway bridges that all maintenance charges will be avoided except those absolutely necessary to insure the present safety of traffic.

COST OF MAINTENANCE OF STRUCTURES.

The annual cost of maintaining a structure will vary from a minimum for a masonry bridge to a maximum for an unprotected

* Halsey James, "Railway Masonry and Bridge Foundations," p. 5. Chicago Railway Age Pub. Co., 1883.

† The Y bridge at Zanesville, Ohio, was of the former type and lasted nearly 70 years. See *Engineering News*, 1900 I, 50.

wooden bridge. Except for slight repairs to the roadway, the maintenance charges for a masonry bridge will be zero.

For a well-designed, carefully-covered wooden bridge on dry foundations, the only charges will be for renewing floor plank and painting the exterior. Such a bridge, if not overloaded, should last 70 years.

The maintenance charges for a steel bridge will be floor renewals, cleaning and painting. The cost of these items will vary with every locality. In many locations painting should be done every two to five years to thoroughly protect steel from rust. Yet there are probably few counties in the State that pay much attention to these matters. The result of such neglect will be that the life of many steel structures will be much less than anticipated, and in many cases the life may terminate in a costly accident.

Floor renewals will be the largest maintenance charge with all types of non-permanent structures, and even with exposed Howe or combination Pratt trusses the trusses will outwear from four to six floors and from two to three sets of stringers and floor beams. If the type of floor and its probable durability is determined, the calculation of the annual cost of renewing the same is comparatively simple.

COST OF INSURANCE.

The annual charge to be made to the account of insurance in the case of non-permanent structures is very difficult to determine. A hole in the floor of a bridge may cause the loss of a valuable animal or fire or flood may destroy the whole structure. In the case of many structures not carefully looked after an accident causing loss of life is highly probable in the course of time. The annual charge for such accidents must be accounted for either under this head or by decreasing the estimated life of the structure and thus increasing the annual charge to the sinking fund.

The annual charge for insurance may vary from zero in a locality where structures are cared for and great floods uncommon to a comparatively large sum where these conditions are reversed. The conditions in Pennsylvania, for instance, have been especially severe, and in New Jersey even masonry structures have suffered.

Although it may be impracticable to attempt to give a definite value to the annual charge for insurance in a given case, the fact that one type of structure is less liable to accidents than another must not be lost sight of. If in a given case the items of annual cost other than insurance for a masonry bridge and for a steel bridge are nearly the same, the masonry structure should certainly be adopted.

SUMMARY.

To determine the most economical bridge for a given location, prepare plans for bridges of various types fulfilling the same conditions. Carefully compute the cost of building each type of structure or receive bids for the same.

The annual cost of maintaining bridge structures of masonry will be the interest on their first cost. With all other types of structures, in addition to the interest on the first cost, varying sums should be added for a sinking fund to replace structure when worn out, for maintaining the structure in condition for use and for insurance against accident to the structure or the traffic it carries.

EXAMPLE.

As an example illustrating the method of applying the principles just outlined, the following actual case will be considered:

Data: Roadway crossing a barranca.

Top width of barranca	171	feet.
Bottom width of barranca	30	"
Depth from grade to bottom of water course	45	"

Preliminary estimates:

For a 50-foot arch, 20-foot roadway of stone or concrete with earth fill, side slopes 1½ to 1	$10,800.00
For steel arch, 46-foot span, 20-foot roadway, 4 girders, buckle-plate floor of concrete and asphaltum, stone abutments and earth fill	9,900.00
For a steel trestle, 160 feet long 16-foot roadway, buckle-plate floor of concrete and aphaltum, concrete abutments and piers.	6,259.00
Actual bid on trestle bridge	6,926.50
Estimated annual cost for repairs on steel arch for paint and asphaltum	50.00
Estimated annual cost for repairs on steel trestle for paint and asphaltum	150.00
Engineering and superintendence for either type	350.00

The above are the figures approximately as given by the engineer in charge of the work. That they are approximately correct is shown by the bid on the steel structure. For the purposes of comparison, the total first cost of each may be taken as follows (increasing the estimate ten per cent. and adding the cost of engineering and superintendence):

Stone or concrete arch	$12,230.00
Steel arch	11,240.00
Steel trestle	7,235.00

The annual cost of perpetually maintaining bridges of the above types, with interest at four per cent., assuming the life of the steel structures to be fifty years, would be:

Stone or concrete arch, 20-foot roadway.

Interest on first cost	$489.20

Steel arch, 20-foot roadway.

Interest on first cost	$449.60
Sinking fund to accumulate $3000 in 50 years	19.65
Maintenance	50.00
Total	$519.25

Steel trestle, 16-foot roadway.

Interest on first cost	$289.40
Sinking fund to accumulate $5000 in 50 years	32.75
Maintenance	150.00
Total	$472.15

Giving full value to the permanent portions of the steel structures and making no allowance for insurance, it is seen by the above comparison that the annual cost of the stone structure is approximately equal to that of the steel trestle and that the steel arch is considerably more expensive.

If the steel trestle had been made the same width as the stone arch and steel arch structures, its annual cost would have been greater than for the steel arch. The stone structure is therefore the most economical, and at the same time, if properly constructed, is less liable to accident and deterioration through lack of proper maintenance.

Another example taken from estimates made by the writer:

Bridge, 30-foot span; 20-foot roadway, subjected to heavy wagon traffic.

Assumed life of wooden truss, 16 years.
Assumed life of 4-inch floor plank, 4 years.
Assumed life of stringers and joist, 8 years.

Estimated first cost of a concrete-steel girder bridge, 6-inch reinforced concrete floor covered with 3-inch oiled gravel or earth...$884.00

Estimated cost of King post truss bridge on concrete abutments:

Bridge	$200.00	
Abutments	50.00	
		$250.00

Annual cost of perpetually maintaining bridges of above types:

Concrete-Steel Bridge.

Interest on first cost at 4 per cent	$35.36	
Oiling	4.00	
		$39.36

WOODEN BRIDGE.

Interest on first cost at 4 per cent		$10.00
Sinking fund to accumulate $200 in 16 years		9.16
Maintenance—		
Floor plank	$18.00	
Stringers and Floor beams	6.60	
		24.60
Total		$43.76

CONCLUSION.

The writer believes that by a careful study of highway bridge construction, along lines similar to those above outlined, considerable saving can be secured to country communities in the cost of maintaining their bridge structures. This is especially true of irrigated districts that have to maintain a large number of small structures subjected to large traffic. For the eight years from January 1, 1889, to January 1, 1898, the average annual expenditure of one of the interior valley counties of California for bridge work was $22,380.* If this annual expenditure be considered as interest at 4 per cent. on money invested in permanent structures, it would represent an investment of $559,500.

The writer realizes the impracticability of building nothing but permanent structures. Even if bonds are issued the tax on the present generation would be unjustly heavy. He does believe, however, that in many counties by beginning with the smaller culverts and openings as they are worn out, in the course of twenty years the saving to the road fund would be so great that gradually larger temporary structures could be replaced by permanent structures without issuing bonds or materially increasing the road tax.

* "Biennial Report of the California Department of Highways, December, 1898."

THE JET PUMP AS AN HYDRAULIC APPARATUS.

By F. G. Hesse, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 27, 1904.*]

The following treatise considers the jet pump as an hydraulic apparatus in which the jet and the liquid to be raised are both non-compressible and of the same density.

The apparatus is very simple and inexpensive. It contains no moving parts, no valves, and, like the hydraulic ram, it combines both motor and pump; but unfortunately it has the reputation of possessing a very low efficiency, a quality which has so far been the cause of its very limited application.

It is unfortunate that the writings of prominent men on the subject have a tendency rather to increase than to remove this popular estimate.

Prof. James Thomson, the inventor of the jet pump (see "Report of the British Association, 1852-53"), gives, as results of tests, 18 per cent. as the highest efficiency obtainable, but fails to give the conditions under which the tests were made. We can speak of highest efficiency only for given values of h, h_1 and h_2. See Fig., p. 188. Without such statement the word efficiency has no meaning.

Dr. Gustave Zeuner, in his work on draught produced by a steam jet, gives a general theory of the Thomson pump, concluding with the remark that "its efficiency is always very low, that its application is only available within very narrow limits and that its best feature is its simplicity."

In his work, "Vorlesungen über Theorie der Turbinen," Professor Zeuner says: "It is clear from the last four formulas that the theory of this simple apparatus leads to complicated expressions, which, however, enable us, for any given case (for a given apparatus), to determine its practicability and efficiency. But if we endeavor to find those proportions and dimensions which lead to the highest efficiency, we encounter almost insurmountable difficulties."

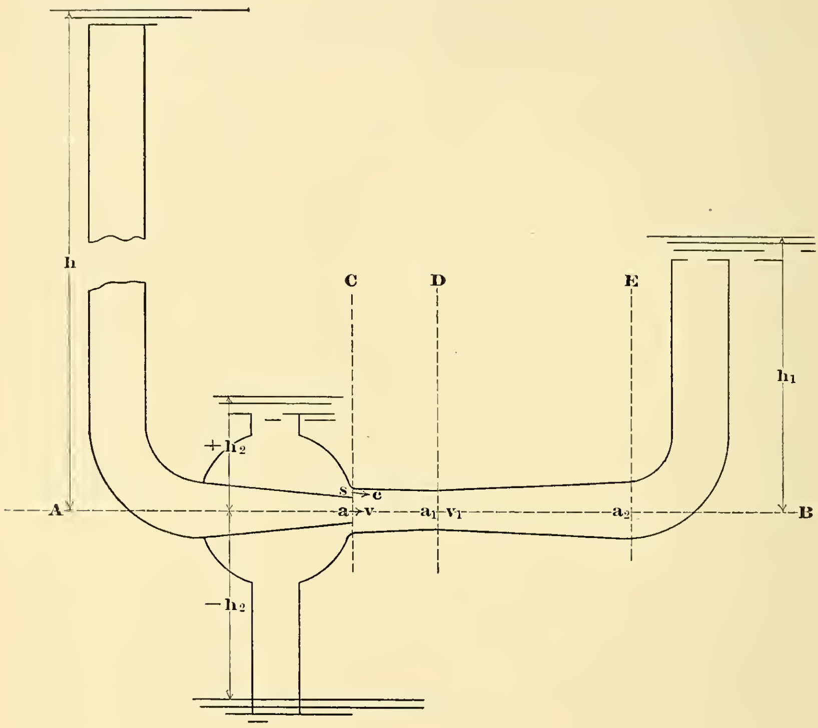
W. T. Macquorn Rankine (see "Proceedings of the Royal Society, No. 123, 1870"), in his paper on the mathematical theory of the combination of any number of jets, applies the principle of conservation of moments to the principal dynamic equation, but only establishes the general fundamental equations. (See *Zeitschrift des Vereins Deutscher Ingenieure,* No. 10, 1866.)

R. R. Werner, professor, Royal Polytechnic Academy in Berlin.

* Manuscript received July 6, 1904.—Secretary, Ass'n of Eng. Socs.

draws attention to an article of Kemp, in Hamburg, published in *Mittheilungen des Gewerbevereins,* in Hanover (1865, No. 2), and then gives a theory of the jet pump, which, in one apparently essential point, differs from all others. (See Note 3.)

Mr. Kemp, in the above quoted article, says: "It is a remarkable fact that the Kemp apparatus still worked well when the suction head exceeded the driving head by 6 to 8 feet, which fact is a convincing proof that the theory of Professor Zeuner can find no application to the Kemp pump." This is true only regarding Professor



Zeuner's treatment without the action of the cone. (See his work, mentioned before, "Vorlesungen," etc., page 68.)

Professor Werner establishes a relation between $\frac{Q_1}{Q}$ and $\frac{C}{v}$, and then says: "For which value of $\frac{C}{v}$ the efficiency is a maximum cannot be determined in general, on account of the intricacy of the above equation, but must be arrived at for each concrete case."

From the foregoing, it is clear that all the writers on the subject have failed to establish formulas for dimensions consistent with highest efficiency.

In the following discussion I consider the stream lines to be parallel with the axis A B, and the loss of energy to be due to impact, in accordance with the well-established law of Cornot.

By far the shortest way is the direct application of the principle of conservation of moments, first applied by Rankine for any number of jets, and by Gustave Zeuner, in his work "Vorlesungen über Theorie der Turbinen"; but, in order to assist the understanding of those who have not paid special attention to the subject, I have based the fundamental equation upon Cornot's principle and shown its identity with that of conservation of moments.

NOTATION USED IN THE FOLLOWING:

$AB =$ datum line.

$h =$ driving head.

$h_1 =$ head to which the water is raised above A B.

$\pm h_2 =$ head above or below A B of the water to be raised.

$h_0 =$ head due to atmospheric pressure.

$a =$ area of nozzle through which water is discharged under head h.

$s =$ area of nozzle through which water is discharged under head $\pm h_2$.

$a_1 =$ area of pipe at section D.

$a_2 =$ area of pipe at section E termination of cone.

$v =$ velocity of water through a.

$c =$ velocity of water through s.

$v_1 =$ velocity of water through a_1.

$v_2 =$ velocity of water through a_2.

$Q =$ a v, volume of water discharged through a.

$Q_1 =$ s c, volume of water discharged through s.

$Q + Q_1 = a\,v + s\,c = B_2.$

$a\,v^2 + s\,c^2 = B_1.$

$\frac{\rho}{\gamma} =$ absolute head at section C.

$\frac{\rho_1}{\gamma} =$ absolute head at section D.

$\frac{\rho_2}{\gamma} =$ absolute head at section E.

$g =$ acceleration of gravity.

$\gamma =$ density of water (weight per cubic foot).

$$B = \frac{\rho_2}{\gamma} + \frac{v^2}{2g} = h_1 + h_0 + \frac{v_2^2}{2g}$$

$\xi_1 =$ coefficient of resistance to flow of water between C and D.

ξ_2 = coefficient of resistance to flow of water between D and E.

ξ = coefficient of resistance to flow of water through nozzles at C.

η = efficiency.

The energy equation between the limits C and D is:

$$\gamma \frac{a\,v^3 + s\,c^3}{2\,g} + B_2\,\gamma \frac{\rho}{\gamma} = \gamma\,B_2 \left\{ \frac{\rho_1}{\gamma} + \frac{v_1^2}{2\,g}(1 + \xi_1) \right\} + \gamma \frac{c\,s\,(c - v_1)^2}{2\,g} + \gamma \frac{a\,v\,(v - v_1)^2}{2\,g}$$

$$\frac{a\,v^3 + s\,c^3}{2\,g} + B_2 \frac{\rho}{\gamma} = B_2 \left\{ \frac{\rho_1}{\gamma} + \frac{v_1^2}{2\,g}(1 + \xi_1) \right\} + \frac{s\,c^3 + s\,c\,v_1^2 - 2\,s\,c^2\,v_1 + a\,v^3 + a\,v\,v_1^2 - 2\,a\,v^2\,v_1}{2\,g}$$

$$\gamma \frac{a\,v^3 + s\,c^3}{2\,g} + B_2\,\gamma \frac{\rho}{\gamma} = B_2 \left\{ \frac{\rho_1}{\gamma} + \frac{v_1^2}{2\,g}(1 + \xi_1) \right\} + \frac{(s\,c + a\,v)\,v_1^2}{2\,g} - \frac{2\,v_1\,(s\,c^2 + a\,v^2)}{2\,g}$$

$$B_2 \frac{\rho - \rho_1}{\gamma} = B_2 \frac{v_1^2}{2g} + B_2 \frac{v_1^2}{2g}\,\xi_1 + B_2 \frac{v_1^2}{2\,g} - \frac{2\,v_1\,B_1}{2\,g}$$

I. That is, $\frac{\rho - \rho_1}{\gamma} = \frac{v_1^2}{2\,g}\,\xi_1 + \frac{v_1^2}{g} - \frac{v_1\,B_1}{g\,B_2}$. See Note 1, below.

Energy equation between limits D and E is:

II. $$\frac{\rho_1}{\gamma} + \frac{v_1^2}{2\,g} = B + \frac{v_1^2}{2\,g}\,\xi_2$$

Eliminating $\frac{\rho_1}{\gamma}$ by adding equations I and II, we obtain:

$\frac{\rho}{\gamma} = B + \frac{v_1^2}{2\,g}(1 + \xi_1 + \xi_2) - \frac{v_1\,B_1}{g\,B_2}$, from which follows:

III. $$v_1 = \frac{B_1}{B_2\,(1 + \xi_1 + \xi_2)} - \sqrt{\frac{2\,g\left(\frac{\rho}{\gamma} - B\right)}{1 + \xi_1 + \xi_2} + \left\{\frac{B_1}{B_2\,(1 + \xi_1 + \xi_2)}\right\}^2}$$

NOTE (1).—If we multiply equation I by γ and a_1 and consider that $a_1\,v_1 = B_2$ we obtain:

$$a_1\,(\rho - \rho_1) = \frac{\gamma\,a_1\,v_1^2}{g} - \left\{\frac{\gamma\,a\,v^2}{g} + \frac{\gamma\,s\,c^2}{g}\right\}$$

We recognize in this the dynamic equation of motion on the application of the principle of conservation of moments to the fundamental equation referred to before.

It is this equation III which solves the problem.

(1) $\frac{B_1}{B_2}$ is a function of s and increases with s; hence v_1 would increase with s without limit if the sign of the radical was +, which, considering the character of the problem, is absurd. We therefore have to adopt the negative sign for the radical.

(2) v_1 increases with a decrease of the work lost by friction and impact.

(3) For a maximum v_1 the expression under the radical sign must be zero, hence:

$$\frac{2g\left(\frac{\rho}{\gamma} - B\right)}{1 + \xi_1 + \xi_2} + \left(\frac{B_1}{B_2(1 + \xi_1 + \xi_2)}\right)^2 = 0$$

$$v_1 = \frac{B_1}{B_2(1 + \xi_1 + \xi_2)} \text{ (and see Note 2)}$$

$$v_1 = \sqrt{\frac{2g\left(B - \frac{\rho}{\gamma}\right)}{1 + \xi_1 + \xi_2}}$$

But since $\frac{B_1}{B_2} = \frac{a v^2 + s c^2}{a v + s c}$, we have:

$$\text{IV.} \qquad \sqrt{\frac{2g\left(B - \frac{\rho}{\gamma}\right)}{1 + \xi_1 + \xi_2}} = \frac{a v^2 + s c^2}{(a v + s c)(1 + \xi_1 + \xi_2)} = v_1$$

NOTE (2).—The maximum value of v_1 can be found in a different way as follows:

The maximum of v_1 corresponds to the least resistance; that is, to a minimum of the work lost. The latter is

$$a v \frac{(v - v_1)^2}{2g} + s c \frac{(c - v_1)^2}{2g} + B_2 \frac{v_1^2}{2g} (\xi_1 + \xi_2)$$

Differentiating, etc., we have

$$(a v + s c) v_1 - (a v^2 + s c^2) + B_2 (\xi_1 + \xi_2) v_1 = 0$$

$$\text{Hence } v_1 = \frac{B_1}{B_2(1 + \xi_1 + \xi_2)} \text{ as above.}$$

Solving for s,

$$\text{V.} \quad s = \frac{a v}{c} \frac{v - v_1(1 + \xi_1 + \xi_2)}{v_1(1 + \xi_1 + \xi_2) - c} \text{ and } \frac{Q_1}{Q} = \frac{v - v_1(1 + \xi_1 + \xi_2)}{v_1(1 + \xi_1 + \xi_2) - c}$$

Substituting in equation I for $\frac{B_1}{B_2} = v_1 (1 + \xi_1 + \xi_2)$

we obtain $$\frac{\rho - \rho_1}{\gamma} = -\frac{v_1^2}{2g}(\xi_1 + 2\xi_2)$$

and neglecting friction, $$\frac{\rho - \rho_1}{\gamma} = 0$$

We have also the following relations:

$$v = \sqrt{\frac{2\,g\left(h + h_0 - \frac{p}{\gamma}\right)}{1 + \xi}}$$

$$c = \sqrt{\frac{2\,g\left(h_2 + h_0 - \frac{p}{\gamma}\right)}{1 + \xi}} \quad h_2 \text{ either } +$$

$$a_1 = \frac{Q + Q_1}{v_1}, \quad a_2 = \frac{Q + Q_1}{v_2}$$

$$\eta = \frac{h_1 - h_2}{h - h_1}\,\frac{Q_1}{Q}$$

The above expressions are based upon an assumed value of $\frac{p}{\gamma}$ between the limits o and $h_0 \pm h_2$, but it is evident that the highest efficiency is obtained for $\frac{p}{\gamma} = 0$. (See equation IV.)

NOTE (3).—The theory of Professor R. R. Werner is based upon the assumption that the jets of water v and c act by impact upon each other until they flow with uniform velocity v_1. Carnot assumes that the masses issuing with velocities v and c impinge against the whole mass flowing with velocity v_1.

With Werner the work lost is equal to $\frac{(v - c)^2}{2\,g}\,\frac{Q\,Q_1}{Q + Q_1}$.

With Carnot the work lost is equal to $\frac{(v_1 - c)^2}{2\,g}\,Q_1 + \frac{(v - v_1)^2}{2\,g}\,Q$.

It can be shown that both expressions are identical if we substitute for v_1 the value found above; that is, $\frac{B_1}{B_2}$.

It can further be shown more directly that both assumptions lead to the same result, in the following way:

With Werner the common velocity $v_1 = \frac{c\,Q_1 + v\,Q}{Q + Q_1} = \frac{s\,c^2 + a\,v^2}{s\,c + a\,v} = \frac{B_1}{B_3} = v^1$, neglecting friction.

OBSERVATIONS ON DRIVING PILES WITH A STEAM HAMMER.

By J. J. Welsh, Member of the Technical Society of the Pacific Coast.

[Read before the Spring Meeting of the Society, May 27, 1904.*]

The lot on which this piling was done is the S. E. corner of Spear and Market Streets, San Francisco, and was formerly a part of the Bay which was gradually filled in, the lot therefore being "made ground."

After six piles had been driven, it became evident that the ground was exceedingly soft, and inquiry among architects, engineers and pile-driving firms showed that the ground here was much more yielding than the surrounding area. This may be explained by the manner of filling in. At that time the lot was occupied by houses on stilts and the sand and rubbish were dumped around the stilts, causing the soft mud to rise almost to the same level under the houses without materially compressing it.

The new building was to be of brick and six stories in height, making necessary a careful determination of the actual resistance of the piles. The softest spot was found by driving piles in a number of places. Here a pile and follower were driven down 105 feet without finding a hard stratum. The following day another pile was driven, which sank one foot in the last two blows. On the next day it required 16 blows to sink this pile one foot, the first three blows having no apparent effect, while the fourth blow started it.

It was decided, as a third test, to load four piles. In order to make the conditions such as would exist under a pier, 11 piles were driven into a trench. The four outer ones were left 18 inches higher than the others, so as to bring the bearing only on these four and to give them the benefit arising from the consolidation of the material near them.

The piles were Oregon pine, 70 feet long, and were 12 to 14 inches at the butts and 6 to 8 inches at the point. The test piles were spaced 4 feet 8 inches on centers for the short span, and 7 feet 1 inch for the long span; on top of the four piles were set four steel plates 14 inches by 14 inches by $\frac{7}{8}$ inch thick, and on top of these were placed two 15-inch I-beams, weighing 1000 pounds each, bolted together to each set of piles in the long span, and upon these

* Manuscript received August 2, 1904.—Secretary, Ass'n of Eng. Socs.

were placed eleven I-beams, weighing 1000 pounds each, which formed the platform. On this platform pig iron was piled. Before putting the platform and pig iron on, levels were taken and bench marks made. The pig iron was brought to the grounds in trucks, and each load was weighed on public scales before being delivered.

The accompanying table gives (1) the conditions and results (actual loads and settlements) for each of the four piles, (2) the calculated safe load for each by three well-known formulas, and (3) the extreme load by the Trautwine formula, which is the only one of the three giving extreme load, defined by Trautwine as the load "that will be just at the point of causing more sinking."

The three formulas are:

Sanders:* $p = \frac{12\, w\, h}{8\, s}$

Engineering News:† $p = \frac{2\, w\, h}{s + c}$†

Trautwine:* $P = \frac{51.52\, w \sqrt[3]{h}}{s + 1}$

where

P = the extreme load on one pile, in pounds;
p = the safe load on one pile, in pounds;
w = the weight of hammer, in pounds;
h = the fall of hammer, in feet;
s = the final penetration, in inches.

The steam hammer, used with piles Nos. 3 and 4, was known as No. 1, the heaviest made. Total weight 9850 pounds, length 12 feet, diameter of cylinder 13½ inches, normal stroke 42 inches, weight of striking part 5000 pounds, distance between jaws 20 inches, width of jaws 8¼ inches.

The steam hammer used is a gravity hammer, raised by steam, then automatically tripped. When the hammer reaches the pile it automatically opens up the steam, which raises it, consequently the motion is automatic, both up and down.

Now, if we figure the striking part of 5000 pounds as the hammer, we hardly measure the efficiency of the machine, important elements being the constant weight of 9850 pounds (nearly 5 tons) on the pile and the rapidity of the blows.

This machine could strike 65 to 85 blows per minute.

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* Trautwine's Civil Engineer's Pocket Book, Editions of 1902 and 1904, page 592, where the Trautwine formula is given in the form: $P = 2240 \frac{0.023\, w \sqrt[3]{h}}{s + 1}$

† *Engineering News*, Dec. 29, 1888, p. 511. For drop hammer, c = 1. For steam hammer, c = 0.1. See *Engineering News*, Nov. 17, 1892, p. 470.

Pile Number.	Type of Hammer.	Number of Blows Struck.	Penetrations* and Falls.	Time of Driving, Minutes.	w, Weight of Hammer, Pounds.	h, Final Fall, Feet.	$\sqrt[3]{h}$	s, Final Penetration,† Inches.	Safe Load, p, in Pounds. Sanders.	Safe Load, p, in Pounds. *Engineering News.* Drop.	Safe Load, p, in Pounds. *Engineering News.* Steam.	Safe Load, p, in Pounds. Trautwine.‡	First Day's Load, 80 Tons; Total, 44,800 Pounds Per Pile. Settlement, Inches.	Second Day's Load,** 144 Tons; Total, 80,640 Pounds per Pile. Settlement, Inches.	Extreme Load, P, by Trautwine's Formula.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Drop	117	24 inches per blow of 8 feet . . .	15	3,080	12	2.289	6	9,240	10,560	. . .	12,958	⅛	⅛	51,932
2	"	92	72 " first blow, 5 feet . . . 18 " per blow; 9 blows, 5 feet	3	3,080	29	3.072	9	14,887	17,864	. . .	12,187	⅛	¼	48,748
3	Steam	62	513 " first blow . . . . . . 24 " per blow, 3 blows . .	2	5,000	3.5	1.518	6	4,375	. . .	5,738	13,966	⅛	⅜	55,864
4	"	120	429 " first blow	3	5,000	3.5	1.518	4	6,562	. . .	8,536	19,552	⅛	½	78,208

*See also column 9.

†See also column 4.

‡Trautwine says: "As to the proper load for safety, we think that not more than one-half of the extreme load given by our rule should be taken for piles *thoroughly* driven in *firm* soils; nor more than one-sixth when in river mud or marsh; assuming, as we have hitherto done, that their feet do not rest upon rock. If liable to tremors, take only *half* these loads." We here take safe load, p = ¼ extreme load, P.

**Left on for a little over two weeks. No further settlement.

In *Engineering News* a comparison of the results obtained by steam and drop hammer is given. In this test a steam hammer, weighing 4500 pounds and having a stroke of 42 inches, was used. From 48 to 64 blows, using a follower, were required to drive the pile the last foot. In the same soil and with a pile of the same dimensions, a test was made with a drop hammer weighing 3000 pounds and falling 30 feet. In this case 16 blows were required, using a follower, to drive the pile the last foot. As the ratio of blows without follower to blows with follower is as one to two, the number of blows required to drive these piles the last foot without a follower would have been only one-half as many. Again, in this case, the weight of the machine, being constantly on the pile, is not taken into consideration.

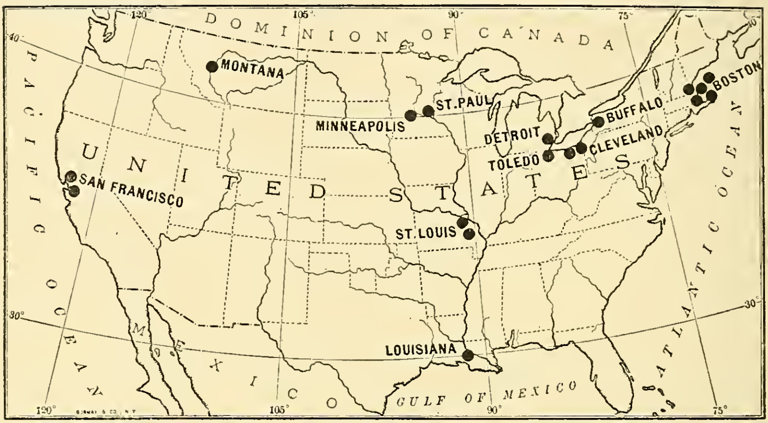
We can readily understand that formulas derived from tests made under different conditions, will vary considerably, and, as the circumstances vary so greatly, it is always well to allow a large margin in calculating the strength of a pile, and a superintendent in charge of the work must depend to a considerable extent upon his own judgment rather than upon results obtained by any of the formulas, and, if any doubt exists, make an actual test.

In conclusion, the results obtained by Wilcoxon & Kearns Co., of Pensacola, from an economical point of view, will be given.

The firm was engaged in the construction of a large wharf and warehouse for the L. and N. Railroad at Pensacola, Fla., which required 7000 piles 60 to 80 feet long. A drop hammer of 4200 pounds was started on a pile which had been half driven with a steam hammer. The hammer had a drop of 60 feet and the pile showed only 1¼ inch penetration to each blow. The live oak cushion block was mashed into pulp. Another pile 75 feet long was driven with the drop hammer without the hood. This took 50 minutes time after it was in the leads, and required 120 blows from the top of the 75-foot leaders. On the next pile of the same length, and 3 feet from the one driven, they used a steam hammer and drove it to the same depth with 130 blows in 90 seconds after it was in the leaders.

This pile had no broomage, while the one along side of it, driven with the drop hammer without a hood, was broomed over three feet. The piles were creosoted, and cost 40 cents per foot net, delivered on the grounds. In using the steam hammer throughout this work, a saving of 21,000 feet of piling was made, at 40 cents per foot, or $8400 total.

Since writing this paper the author has discovered that some of the piles had penetrated through old piles which had been covered up since the filling in. This accounts for the fact that these particular piles could not be driven with the drop hammer, while the steam hammer sent the piles clean through the old piles to the proper depth.



MAP

Showing the locations of the Societies forming

THE ASSOCIATION OF ENGINEERING SOCIETIES.

(Each dot represents a membership of one hundred, or fraction thereof over fifty.)

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

ASSOCIATION
OF
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THE CLEANING AND FLUSHING OF SEWERS.

Discussion by the Sanitary Section of the Boston Society of Civil Engineers at the Meetings of March 2 and April 13, 1904.*

J. L. WOODFALL.†—Some years ago, engineers believed that all sewers should be laid to a regular or hydraulic grade. It was supposed that any considerable sag in the sewer would cause the solids to collect and plug the sewer. Under the combined system the fear of stoppage was to a great extent well founded, but with the advent of the separate system the danger was to a large extent removed.

Soon after the adoption of the separate system, the question of the pollution of inland waters was taken up in the State of Massachusetts. This was followed by the valuable experiments of the State Board of Health and the building of filtration works for the purification of the sewage of several towns.

Before the question of the pollution of inland waters was taken up by the Legislature of Massachusetts, the problem of the disposal of sewage was, to a large extent, solved by building a sewer or sewers to the nearest water course or large body of water, although in some cases the question of the disposal of the sewage at such a point as to give little trouble was well considered. Under the old method of disposal it was usually a simple problem to build the sewers on proper grades to the nearest point of discharge, but on the introduction of the filtration scheme it was often found that, to deliver sewage onto a proper filtration area, it was necessary to cross some considerable valley.

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Naturally, following the old idea that sewers must be laid on the hydraulic grade, the first deduction of the engineer was that the sewage must be delivered, by gravity, to the low point and then pumped to the filtration area, or that embankments or a trestle must be built so that the sewer could be built on the hydraulic grade. I need hardly say that both of these methods are expensive, and in some cases the cost makes them practically prohibitive for small towns. The engineer was thus led to devise some other method to reach a filtration area when separated from the town by a valley. Naturally he adopted the so-called inverted siphon which had long been in use in the distribution of water for domestic purposes.

When I promised our Secretary to read a paper on the inverted siphon I thought it might be possible to give a general history of the subject, but with the small amount of published matter on the subject I found that it would be necessary for me to obtain data from all the engineers who have used this form of construction. Time not admitting of this I am compelled to give a description of the design and construction of inverted siphons which have come under my personal observation with such deductions and suggestions as I deem may be of interest and possible value.

In order to give a clear description of these inverted siphons it is necessary, in each case, to include a short description of the system and the disposal plant.

GARDNER (MASS.) SIPHON, BUILT IN 1890.

The system was designed in 1888 and included about 18½ miles of sewers and the disposal works. One main treatment area and one smaller area were recommended. In this part of the description only the larger area will be considered.

To reach the main disposal area it was necessary to lay the outlet sewer in Conant Street, cross Broadway and the valley of Pond brook,—the lower end of Conant Street and Broadway being at a lower elevation than the filtration area. Three methods for delivering the sewage to the filtration area were available. 1st. Build the outlet sewer in Conant Street as far as possible, then in private land, and cross Broadway at a point where it was higher than the filtration area, then build a bridge over the valley of Pond brook. 2d. Build the outlet sewer to a point near the junction of Conant Street and Broadway, then pump the sewage to the filtration area. 3d. Build the sewer in the lower end of Conant Street and across the valley of Pond brook in the form of an inverted siphon. The third method was adopted.

The outlet sewer in Conant Street is a twelve-inch vitrified pipe laid on a grade of 1 foot to 100 feet. The end of the sewer is 1050 feet from the settling tank which is located at the highest point in the filtration area. At the end of the vitrified pipe sewer a manhole 6.1 feet deep was built. From this manhole to the settling tank an inverted siphon was built. The pipe was laid with from 4 to 4½ feet cover and all joints were leaded. At Pond brook a bridge ten feet long was built to carry the pipe and the pipe was covered with a box. The low point in the siphon is near the brook. At this point a small filter bed was built, a 12 x 8-inch T was inserted in the siphon line and a gate placed at the end of the 8-inch branch. When this gate is opened the sewage, in the inverted siphon, is discharged onto this filter bed. All changes in direction and grade were made gradually with straight pipe until the settling tank was reached. The pipe was laid along one side of the settling tank. After passing the settling tank the pipe was turned at right angles by means of an elbow. It was then carried straight for about twelve feet and then turned upwards by means of an elbow, and then turned into the tank with another elbow, the vertical distance between these last two bends being about three feet.

The settling tank is 15 feet by 20 feet and is separated into two compartments by a 12-inch wall. At one end of the tank a wooden box was built on top of the 12-inch wall. The end of the inverted siphon discharges sewage into this box. Openings from this box to each tank and a swing gate allow the discharge of sewage into either tank. Sewage flows from the other end of the settling tank to a small gate chamber from which it is diverted to the different filter beds. Stop planks near the outlet end of the settling tank retain floating substances. The depth of sewage in the tank is five feet and the water line of the siphon, at its outlet, is about one foot above the surface of the sewage in the settling tank.

Having given a general description of the inverted siphon and a part of the treatment plant I will now give a more detailed description of the inverted siphon and a few remarks as to its working.

The inverted siphon is built with twelve-inch iron pipe. It is 1050 feet long and the low point is 24 feet below the outlet. The outlet is 1.4 feet lower than the beginning of the inverted siphon and the hydraulic grade, using the actual length of pipe as a basis of figuring, is 1.33 feet in 1000 feet.

The inverted siphon was put in operation in the spring of 1891. The blow-off gate was opened several times in the summer of 1891. The blow-off gate was next opened in the summer of 1896. About three or four years ago the blow-off gate was again opened by the

State Board of Health, for experimental purposes. It has not been opened since that time.

The upper end of the inverted siphon is connected with the sewer by means of a manhole. No sump chamber was used.

A considerable amount of sludge was discharged onto the filter bed each time the blow-off gate was opened. No appreciable difference in the amount of sludge was noticeable at the different times this gate was opened. In this inverted siphon the following action has been noticed. For some time after the settling tank had been cleaned, the solids would collect slowly and no scum would appear on the surface of the sewage. The superintendent would notice this fact. On his next visit he would find the surface of the sewage covered with a considerable amount of scum. As I observed this action it seemed to me that the siphon became partly clogged, the head was increased and the accumulated mass of sludge would then be discharged rapidly into the settling tank. Every day a considerable amount of rags and other solids, which do not break up, are discharged into the settling tank. A good example of how an inverted siphon will clean itself was given by the siphon several years ago.

The Superintendent of Streets was macadamizing some streets. After the stone dust had been put on the streets but before it had become solid, stormy weather set in and a considerable amount of dust was washed into the sewers through the open manhole covers. This was followed by a very heavy rain. The stone dust and silt which had been accumulating in the inverted siphon was discharged into the settling tank. When the settling tank was cleaned from 3 to 4 cubic yards of this material was removed. Measurements by the State Board of Health indicate that the average daily flow at this date is 200,000 gallons. The average velocity of flow in the inverted siphon is about 4/10 of a foot per second.

THE ANDOVER (MASS.) INVERTED SIPHON.

The sewerage system for Andover, Mass., was designed in 1894 and contemplated discharging sewage into the Merrimac River. The Andover Sewerage act, passed by the Legislature in 1895, gave the town of Andover authority to build this outlet, but one section of the act, dealing with the possible creation of a nuisance on the shore of the Merrimac River within the town of North Andover, and the abatement of the same, led the Andover Sewer Commissioners to abandon this proposed outlet and adopt the filtration method of disposing of the town's sewage. This resulted in the separation of

the town into a high and a low level area. The sewage from the high level flows to the filtration area by gravity while the sewage from the low-level area is pumped to the high-level sewer at a point near the outskirts of the town. The system, as planned, includes about 21 miles of sewers. The system on these lines was partly constructed in 1898. In order to reach the filtration area it was necessary to cross a valley. This was done by means of an inverted siphon. The outlet sewer is a 15-inch vitrified pipe laid on a grade of 1 foot in 1000 feet.

The inverted siphon was laid in the same general manner as that already described for the Gardner siphon. It had a blow-off gate and filter bed at the low point. It differs from the Gardner siphon of 1890 in the following particulars. The upper end of the siphon started from a screen chamber. This chamber was intended to remove large solid matter. For flushing the inverted siphon a water gate was placed at the head of the inverted siphon. Below this gate a 12-inch by 6-inch Y was inserted and a 6-inch water main, properly gated, was connected with the 6-inch branch. The outlet discharged into a settling tank.

This tank is 50 feet long 8 feet wide and has a circular top. The depth of sewage is 4.5 feet. The sewage flows through the settling tank, passes under a brick wall at the end of the tank, then flows over a brick wall with a stone cap into a dosing tank having a capacity of 5000 gallons. The dosing tank is covered with a brick house. The sewage is discharged from the dosing tank into a gate chamber by means of an 8-inch Miller siphon. From this gate chamber sewage is delivered to the filter beds. The inverted siphon is laid under the end of the settling tank for about 2 feet, it is then turned up by means of an elbow, and the end is at a point 2½ feet below the surface of the sewage in the tank. The inverted siphon is a 12-inch iron pipe 4980 feet long. The low point is 53.5 feet lower than the surface of the sewage in the settling tank. The upper end of the inverted siphon is 12.5 feet higher than the surface of the sewage in the settling tank.

The hydraulic grade, using the total length of pipe as a basis of figuring, is 2.51 feet to 1000 feet.

Measurements made by the State Board of Health show that the average daily flow is about 125,000 gallons, and the velocity of flow in the inverted siphon 25/100 of a foot per second.

I have been informed that the blow-off gate has never been opened in order to flush the inverted siphon, and that it has been flushed but once with water from the six-inch water pipe. I under-

stand that practically all the solids pass through the inverted siphon. No trouble, so far as I am informed, has been given by the inverted siphon.

GARDNER (MASS.) INVERTED SIPHON, BUILT IN 1900.

In 1900 the population in that section of the town requiring a second disposal area, as indicated in the original report, had become so great that sewers and a second filtration plant were built. Legislation was secured by the town which allowed them to take land for sewage disposal outside of the town limits. This legislation made it possible for the town to secure land in the town of Templeton which was satisfactory as a disposal area. In order to reach this area it was necessary to cross the valley of the Otter River. This was done by means of an inverted siphon. The method of construction is similar to that previously described. No blow-off gate was used as the low point is in the bottom of the Otter River. The upper end of the inverted siphon has a gate and a 6-inch water pipe is connected by means of a T.

The complete method of treatment is to first pass the sewage through a settling tank, second through coke strainers and then through sand filters. Experiments made on coke strainers by the State Board of Health indicated the possiblity of treating sewage successfully without the settling tank. In order to see if this could be done the settling tank was not built and the sewage was delivered direct to the coke strainers.

As far as removing solids, it was found that the coke strainers did all that was expected, but it was found that a large amount of sludge was deposited on the surface of the coke. In winter it was practically impossible to remove this sludge. During the winters of 1901 and 1902 the coke strainers were used, but towards spring they were covered with such a depth of sludge as to necessitate putting them out of service and to deliver crude sewage onto the sand filters. Last fall settling tanks were built and connections made with the inverted siphon. For about three months sewage has been running through gate chambers and a by-pass located at the settling tank, but the tanks have not been used as they are not fully completed. In making this connection five elbows were used and a vertical rise of about ten feet. No difference in the working of the inverted siphon has been observed on account of this alteration. With the exception of these elbows changes in line and grade were made with straight pipe until the coke strainers are reached. At this point the pipe is turned up by means of an elbow and then

turned into a chamber with another elbow, the vertical pipe being about seven feet long.

It was considered desirable to deliver the sewage in doses onto the coke strainers. In order to do this the last 427 feet of the outlet sewer was built with thirty-inch vitrified pipe. This pipe together with the twelve-inch outlet sewer, gave a storage capacity of about 2200 cubic feet. The thirty-inch pipe empties into a small chamber in which are located two eight-inch Miller siphons so connected as to work together. These siphons discharge into a second small chamber the outlet of which is the inverted siphon. A twelve-inch by-pass makes it possible to give a steady flow through the inverted siphon. When a steady flow is used a considerable amount of sludge accumulates in the inverted siphon. This sludge is flushed out when the by-pass is closed and the Miller siphons are put in operation. When the Miller siphons are in operation and the 2200 cubic feet of sewage is discharged rapidly to the coke strainers sludge does not accumulate in the inverted siphon. The first discharge in the morning is to all appearances clear water while the following discharges have a considerable amount of solids. This indicates that all solids have been flushed out during the night and in the morning the inverted siphon is filled with practically clear water.

It takes about thirteen minutes to discharge the storage of 2200 cubic feet by means of the two Miller siphons. In the summer of 1901 it was noticed that this time had increased to thirty-seven minutes. Between flows of the Miller siphon the gate at the upper end of the inverted siphon was closed and the inverted siphon was flushed with water from the six-inch water main. The gate on the inverted siphon was then opened and the combined water from the water pipe and the sewage discharged by the Miller siphons were used to flush the inverted siphon. After this flushing the time of discharge of the Miller siphons was reduced to twenty-three minutes. The Miller siphons were kept in operation but no more water was used from the water pipe. A few days after the flushing there was delivered at the coke strainers a mass of rags, combined with an iron rod about one foot long, a piece of large wire about twenty inches long bent in such a way as to be about ten to twelve inches long, an empty quart can and a few smaller pieces of metal. After the inverted siphon had freed itself of this obstruction the time of flow from the Miller siphons was thirteen minutes.

Probably the iron rod and wire were put into the sewer through the holes in the manhole covers. I leave it open for any one to give an explanation as to where the quart can came from. They prob-

ably reached the inverted siphon through the by-pass at the end of the main sewer.

The length of this inverted siphon is 2600 feet and the size 16 inch.

The low point is 32.5 feet lower than the outlet.

The upper end is 5.7 feet higher than the outlet and the hydraulic grade, using the actual length of pipe as a basis of figuring, is 2.2 feet to 1000 feet.

The average daily flow, as measured by the State Board of Health, is 250,000 gallons.

Experiments made by the State Board of Health on the loss of head in the Gardner inverted siphon built in 1890 give the following results:

The inverted siphon was not flushed from July, 1898, until February, 1899. With a flow of 398,000 gallons per day the loss of head, before the inverted siphon was flushed, was 886/1000 of a foot, and with a flow of 422,000 gallons per day a loss of head of 940/1000 of a foot.

After flushing the loss of head was 230/1000 of a foot with a flow of 255,000 gallons per day and 509/1000 of a foot with a flow of 412,000 gallons per day. The theoretical loss of head with the flow of 255,000 gallons per day being 102/1000 of a foot and with a flow of 412,000 gallons per day 263/1000 of a foot. The theoretical head was figured for clear water. This shows that the loss of head after flushing is about twice the theoretical loss of head as figured for clear water and before flushing about three and one-half times the theoretical loss of head.

These experiments indicate that in figuring the size of an inverted siphon to carry sewage a loss of head of, at least, three and one-half times that found for clear water should be used.

WHEN TO USE AN INVERTED SIPHON.

I can give no set rule as to when to use an inverted siphon. I should prefer not to use it if it can be avoided without extra cost or the building of an unsightly structure. When it is necessary or preferable to use this form of construction, I should not hesitate to adopt it, as my experience with the inverted siphons at Andover and Gardner shows that no trouble will be given by them if properly constructed.

ANOTHER FORM OF INVERTED SIPHON.

A number of short inverted siphons have been built which differ in their form of construction from those I have already described. At each end of the inverted siphon is a chamber or man-

hole. The chamber at the upper end of the inverted siphon has a sump and often a sump is built in the chamber at the lower end of the inverted siphon. Usually two pipes are used, and provision is made for cleaning them by building an overflow to a brook. The chamber, at the upper end of the inverted siphon, is divided into two compartments by a wall. A gate in this wall, when closed, prevents sewage from flowing to the inverted siphon and it then flows to the brook through the overflow. It is then possible to pump the sewage from the sump chamber or chambers and the inverted siphon. The inverted siphon can then be cleaned and inspected. A modification of this form of construction is to build chambers in duplicate with a pipe from each chamber. Gates allow the sewage to be diverted to either pipe, so that, while one pipe carries the sewage the other can be cleaned. The good point of this form of inverted siphon is the fact that, not only can it be cleaned out but that it can also be inspected. Its bad points are, first, the collection of sludge at a point from which it is often difficult to remove it, second, the labor necessary to remove this sludge and the probability that it will be neglected. If neglected the sump hole fills up and is of no use. Third, the greater danger of stoppage, this danger being dependent on the neglect to keep the sump chambers cleaned out.

One of the arguments advanced for this form of inverted siphon is that one pipe may be used until such time as the amount of sewage requires the use of the second pipe, thus giving a greater velocity than would be the case if one pipe were used the capacity of which was equal to that of the two pipes. This theory may be all right when the lower end of the pipe has a free outlet but when a sump chamber is used at this point the reduction of velocity will be so great that solids will be deposited and the inverted siphon will soon be plugged unless these solids are removed. The only stoppage of an inverted siphon I have heard of is in one built in this manner.

BEST DESIGN FOR AN INVERTED SIPHON.

I think the best form for an inverted siphon is that used in the Gardner siphon of 1900 but I should place a blow-off at the low point, if possible.

OPEN MANHOLE COVERS.

Open manhole covers provide a means for ventilating the sewers during a greater part of the year, but a large amount of dirt reaches the sewers through the holes in the covers. Many of the stoppages are caused by boys dropping sticks through these holes. One of

the greatest dangers of stoppage, in an inverted siphon, arises from the use of open manhole covers.

When purification works are built the amount of sewage to be treated is unnecessarily increased during storms or the melting of snow if open manhole covers are used.

I consider the objections to the use of open manhole covers, in a system built to carry house drainage only, far outweigh any benefits that may be derived from their use.

Mr. Leonard Metcalf.—I would like to ask the speaker in what way he figures the theoretical loss of head by friction in the siphons referred to, just as a matter of record, as it would make the paper a little more complete.

Mr. Woodfall.—I took a very short method. I obtained the information from Mr. Johnson, of the State Board of Health, who had already worked it out. I refer to Mr. Johnson.

Mr. William S. Johnson.—It was figured the same as for water pipe, assuming that pure water was flowing through the pipes. Weston's tables were used.

Mr. Freeman C. Coffin.—How was the actual loss ascertained?

Mr. Johnson.—A box was constructed at the lower end of the siphon where it discharged into the settling tank, by means of which the level of the sewage was raised sufficiently to make the pipe flow full for its entire length. Hook gages were set up at each end and accurate levels were run between the hook gages.

Mr. Coffin.—The actual difference in the levels of the water was shown?

Mr. Johnson.—Yes.

Mr. W. D. Hubbard.—I would like to ask the speaker whether he ever noticed that grease collected in the iron siphon?

Mr. Woodfall.—I have very often looked at the outlet of the old Gardner siphon, and the pipe, except for a little rust, appeared just the same as it did the day it was put in. Last fall when we broke the siphon which had been in operation since 1901, I looked into the pipes, and those pipes looked exactly like a new water pipe. There was apparently no collection of grease or hard substance in the pipe.

Mr. Hubbard.—Do the drains that lead from the houses have traps?

Mr. Woodfall.—Yes, the house drains are trapped.

Mr. Hubbard.—The reason I speak of it, is that at Concord, when the system was first constructed and connections made with the houses, the old form of placing a 4-inch trap on the house drain inside of the wall was in use in almost all cases, but as soon as we commenced to use the sewer system the cold air from the sewer passing through the trap congealed the grease in the trap, so they had to call for a plumber to have it removed. After a discussion with the Board of Health, the plumbing was changed, and the running trap was discontinued, and the grease now passes out into the street sewers.

We have, at Concord, Massachusetts, two river crossings, which are inverted siphons, and they are operated by storing the flow in a chamber, and discharging it automatically through a Van Vranken automatic tank, and the siphon chamber looked as though it were made of marble. There was a deposit of grease from one and one-half to two inches in depth over the iron-work in the chamber, and I didn't know but that was possibly so in the case of an inverted siphon of considerable length,—that the grease would form on the inside of the pipe. You say it does not?

Mr. Woodfall.—We have never seen it. I would say that, in the new siphon chamber at Gardner, I observed the same thing you indicate, only not to the extent you speak of; grease appears on the walls of the chamber, and of course there is a collection of grease, matches, pieces of paper, etc.

Mr. Hubbard.—I have some notes on the siphons at Concord, which may possibly be of interest.

We have two river crossings where the pipe goes under the bed of the river, forming an inverted siphon, and the flow is regulated by a flushing tank placed in a storage chamber at the upper end of each siphon.

The capacity of the siphon chamber at the first siphon is 7400 gallons, and the fall from the bottom of the chamber to the invert of the sewer on the opposite side of the river is 2½ feet. The siphon is an 8-inch cast-iron pipe, 125 feet long, with a fall of 6 inches from one side of the river to the other. When the sewer was first constructed and nothing was used but clean water, the siphons worked very well indeed, and we had no trouble. As soon as the house connections were made, the flushing tank failed to operate satisfactorily. Instead of operating automatically at intervals, it operated continuously, and we did not seem able to find any method of making it operate in the way it was designed to. There was a tilting pan under the flushing tank, and this pan would fill with an accumulation of grease, rags and sand, and the result was

that it would not work. Our foreman, who was somewhat of a mechanic, drilled a hole in the top of the siphon, and put on an automatic apparatus for breaking its seal. When the water rises in the chamber, it raises an ordinary ball float, which is connected to a lever arm. On the opposite end of the lever arm is a plug which fits into the opening in the siphon leg and closes it. Then, when the siphon begins to operate the ball drops, and by the time the sewage is all discharged from the chamber the ball is in such a position that the lever arm is raised and the plug is released.

The device has worked very satisfactorily indeed. As I said before, we have had grease in the chamber itself, but that is the only place we have had it. It has never troubled us at all in the pipe under the river.

The other siphon is smaller, the capacity of the siphon chamber being 1570 gallons. The length of the siphon is 155 feet, and it is an 8-inch cast-iron pipe with a fall of 6 inches,—the lowest point being 5.72 feet below the invert of the trunk sewer. The water level in the chamber at the time of discharge is 5 feet higher than the level of the trunk sewer. At the end of the discharge it is 2 feet. We had similar trouble with the flushing tank not operating satisfactorily, but it was remedied in the same manner, by drilling a hole in the top of the siphon and putting on an automatic apparatus for breaking its seal.

The sewerage system was built in 1898 and 1899. In the winter of 1902 this siphon chamber was temporarily plugged, the siphon pumped out and inspected, and it was found to be in the same condition that Mr. Woodfall described. In the pipe no silt, grease or deposit was found. It was clean from one end to the other.

In regard to open manhole covers, we have covers that have 37 holes in them, $\frac{3}{4}$ of an inch in diameter, but provision was made to catch any sand that might get in through the holes, or sticks that mischievous boys might put in through them, by means of dust pans made of wrought iron. In order to provide some means of allowing the water to escape, a hole was drilled in the bottom of the dust pan, and the result is that all the finer material passes through that hole and goes down into the sewer. This grit causes excessive wear in the water end of the pump, the linings soon cut through, and in consequence have been renewed three times.

One other point about the open manhole cover. The idea is that they ventilate the sewer. I do not think we have one out of our whole 144 that acts as a ventilator in any manner whatever. The covers, when they were originally set, were placed level with the top of the street. The sewer trenches settled anywhere

from $\frac{1}{2}$ an inch to 3 inches. The street department resurfaced the streets, and in some places they covered the manholes perhaps $\frac{1}{2}$ an inch, so that every team that comes along drives dirt into those perforations and practically blocks them up entirely. Then, again, in winter, all teaming is in the middle of the road, which makes a depressed area between banks of snow, and as soon as the snow melts the water runs through the perforations in the covers, and we see the effect of it in our pumping.

Mr. Woodfall.—I would say that with our Miller siphon the only trouble we have is that at times rags will catch on the rim as they go over. Once in a while we have to clean them out.

As to the tilting-tank, I don't wonder you have trouble with it. In fact I think that it has always given trouble, but the way you have fixed it, probably, has removed all trouble.

Mr. Felton.—I would like to ask Mr. Hubbard whether it is not having the holes in the manhole covers between the knobs that causes them to stop up? I don't believe they would stop up if the holes were in the tops of the knobs.

Mr. Hubbard.—I could not say as to that as I have never tried it.

Mr. Felton.—I think that if you should ventilate through your connections as we do, or have the holes in the tops of the knobs in the manhole covers, there would not be so much difficulty. We ventilate directly through the connections, which very few do.

Mr. Woodfall.—A great many of our manhole covers in Gardner were open. We have taken many of those out and had them cast as solid covers. I think you would find it economy to get the covers cast over and have them solid.

I think if we omit the traps and get ventilation through the roof, we get the most ideal ventilation.

Bertram Brewer.*—I am not prepared with an address, but I thought I might say something which would be interesting. In regard to siphons, we have one in Waltham that passes under the Charles River. The outlet of our system is on the south side of the river, and perhaps two-thirds of the sewage comes from the north side. This sewage passes under the river through a 24-inch iron-pipe siphon. It is very much the same kind of a siphon as that described by Mr. Woodfall, with a sump at the lower end.

I will say, in regard to the care of it,—because that seems to be the practical point you are all interested in to-night,—that we have no special difficulty. Whenever we flush the sewer we clean

* City Engineer, Waltham, Mass.

out the sump, and it is done by a process which has been handed down to me by my predecessor. He connected the manhole over the sump directly with the water main in the street and got up an ejector, which is let down into the sump, and is operated by a jet of water introduced from the water main. The sump is very readily cleaned out, the jet being so strong and the force produced so great that even stones nearly as large as my hand will come out.

Mr. Woodfall.—I would like to ask the gentleman where the material goes to?

Mr. Brewer.—The ejector is introduced at the sump and the material comes up into the street and is cleaned out there. The drop from the street to the bottom of the sump is about 10 or 12, or perhaps 15 feet, and we have no difficulty in keeping the siphon perfectly clean in this way.

Now, a few words in regard to the system of sewers in Waltham and the general method of flushing.

We had a diphtheria epidemic in our town, and the school children were principally affected. Those who know about diphtheria, know that there is no better place to cultivate the disease than within the four walls of a schoolroom; but the Board of Health wanted to find some other cause, so they went around looking at the sewers, and they concluded that the sewers caused the trouble, and thereupon it became necessary to make a very distinct and clear statement as to our method of caring for the sewers, and also, so far as we could, to disprove the erroneous impression that diphtheria germs floated in the air above the manhole covers.

Our system in Waltham consists of about 38¼ miles, and over 50 per cent. of it is 6-inch pipe, 25 per cent. is 8-inch pipe, and the rest larger sizes up to a main of 32 inches by 55 inches.

Now, in regard to the manhole covers, perhaps I might speak of that, because we have all had our experience with perforated manhole covers. When our system was introduced, it was very strongly recommended that we introduce a system of tight manhole covers, and the Commissioners discussed the matter pro and con. After they had discussed the matter, they decided that they would have the manhole covers perforated, and they proceeded to spoil every manhole cover in the city. Men went around and bored holes in all the manhole covers, and they bored so many holes and so close together that when a heavy team would go over one of them, it would smash it, and we have had to replace them in a large measure on that account. We tried to stop up the holes, by a mixture of iron filings and sal ammoniac, put into the holes. That lasted for a few years. I also tried the scheme of plugging up the holes by

riveting them, but I have not been able to get the city government to give me money enough to complete the work. For my part, I believe in tight covers.

Our system is ventilated through the roofs of the houses. We have almost no running traps. A few were put in when we started the system.

Now, there is a great difference of opinion about this matter of frequency of flushing. So far as I can find out from all I have read on the subject, some say we should flush as often as every three or four weeks, and some oftener, and some think we should let the sewers go until they fill up and then flush them. It is somewhat a matter of expense. I don't know whether any of you gentlemen live in a city where the tax rate is high and the people are poor, but I do, and they want us to give them good service, that is up to date, and not extremely expensive, so we have struck what we think is a happy medium in regard to flushing. We start early in the spring, just as soon as the ground thaws out sufficiently, and go all over the system and make an inspection. We have pans under the openings of the manhole covers, and those pans are cleaned out, and the manholes cleaned out, and the sewers inspected. In fact we have a sort of spring cleaning day. And after that, during the summer season, we have averaged (during the last four years) flushing five times in the season. And then again, in the fall, just before winter opens, we have another wash day. We go all around and examine the system and clean out the manholes and the pans again. The cost of this work of flushing during the last year—I don't mean the cleaning of the pans, but just the flushing alone—including practically all the incidentals, was $6.56 per mile. That includes labor and the horse and wagon and such repairs as would naturally apply to the business.

In regard to the method of flushing, we have the same scheme which has been adopted in Newton and in Medford. Where the manholes at the summits are a long distance from hydrants, we have introduced direct connections with the water mains and put flap valves on the pipes. Of course, as you all know, we fill the manhole, and lift the flap and flush the sewer. There are about 104 of these flushing manholes in the city. There are many places where we have not been able to get money enough to do that. In places where we could get along with 150 feet of hose, or so, we flush by hand with a hose, and there are 117 of those in our system, so we have in all 221 places where we flush regularly, and this is done by a regular system. We made a flushing map of the city, and the

manholes are numbered in rotation, the object being, of course, to flush in the most effective way from the highest point down.

It may be interesting to say something about the stoppages in our main sewers. I have kept a very careful record of them, especially in the last few years, and I find in 1903 there were 15 stoppages in the main sewers. Eight of them were in 6-inch pipes, 6 in the 8-inch, one in the 10-inch. Of these stoppages 8 were caused by roots from trees. That is our great difficulty in Waltham, roots from trees. One was caused by a brick; two by sticks; one by the ribs of an umbrella; one by paper; one by ice; and one we could not find out the cause of. The average number of stoppages in the main sewers in the last four years in Waltham has been 14.

Mr. Hastings.—I would like to ask Mr. Brewer if in flushing he uses a hydrant, or flushing manhole with a tripping gate?

Mr. Brewer.—We use a 2½-inch hose.

Mr. Barnes.—I would like to inquire as to the time it takes to flush the manholes?

Mr. Brewer.—I think I stated there were 104 of one and 117 of the other. As I recall, I should think it took perhaps a third longer to go around to the manholes than it does with the hose, but, on the other hand, one man can do that, and it takes two or three to do the other and from three and one-half to four days.

Mr. Barnes.—It takes one man to go around to 300 manholes about two weeks, and it takes two men and a cart two days to go around amongst 30, in my experience.

Mr. C. R. Felton.*—We have had so little trouble with our siphons that the subject seems a simple one to us. All our inverted siphons are short. The longest one is only 80 feet, and in every case they consist of two lines of pipe. We have two lines simply to increase the velocity through one, which is all we use during the early years of the system. These siphons are put in without any sumps whatever, running down from the manhole at an angle of 45 degrees, with one-eighth bends. Three of our siphons have never had a stoppage, and they have been in use from 9 to 11 years. In the other two we have had a stoppage on two or three occasions, but in only one side at a time, and the stoppage was easily removed with the rods.

The velocity through these siphons does not usually exceed 0.7 of a foot per second, but it can be increased by flushing to about 9 feet per second. I should say that the velocity would be not more than a foot and a half approximately, except at times of flushing.

* City Engineer, Brockton, Mass.

One of our inverted siphons is 10 inches and 8 inches in diameter, and the others are 16 inches and 12 inches in diameter. With the flushing velocity, which I judge is in the vicinity of 9 feet per second, even large pieces of brick are brought through. With that velocity I was unable to sink a 9-pound iron regulator ball at the outlet end. It would take it right out again. I had, of course, a string attached to it so that I would not lose it.

In our siphons it seems to me that the sump is really not necessary, although I should think it would be a good thing in cases where there is danger of stoppage; but my ten years' experience leads me to believe that they are not necessary under our conditions.

In relation to the flushing of sewers, all our summit manholes are connected directly with the water main, some with a 1-inch and some a 1½-inch pipe, under a pressure of 60 pounds. We flush most of our sewers once a month, some twice a month, and some not so often.

As to stoppages in sewers, they are practically unknown. I don't think we have had in our sewers more than 4 or 5 stoppages in the last 7 or 8 years. We have never had but one stoppage that flowed back into a cellar so that we found it in that way. We have one sewer on a grade of about 1 per cent. that has only been flushed once in 9 years. I don't think if the sewer is laid properly, with a proper grade, and the joints are of the deep socket type, and you don't leave the scraper in, there is much fear of stoppage.

As to stoppages in connections, I should say we averaged four or five in a year. Last year we had only one. We have 1700 connections. The principal cause of the stoppages in connections has been due to plumbers' testing plugs carelessly left in the pipe. We have one connection that stops up with roots, which after they are cut out grow again, and on one occasion a stoppage from grease which entirely plugged up the pipe.

I suppose the question of minimum grade governs largely perhaps the trouble with sewers. I would say that our large egg-shaped sewer, 30 x 45 inches in diameter, has a grade of only one in 1500. Our 8-inch pipe is limited to a grade of one in 200. When we can't get that we take less. We have some perhaps 1 in 300, or possibly 1 in 400. Our connections we put in on a very steep grade, and perhaps that is one reason that we do not have trouble with them. We put them in at a grade of 4 per cent., usually, calling our minimum 2 per cent.

Mr. Metcalf.—What is the diameter of those connections?

Mr. Felton.—The connections are five inches in diameter.

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When you try to connect a 6-inch pipe with a 5-inch Y connection, it causes trouble. We have the Douglas shoe factory, which employs some 2500 persons, connected with a 5-inch connection. Five inches is ample, and I think better than four or six.

Mr. Brewer.—How is the connection ventilated?

Mr. Felton.—The ventilation is right through the house. We allow nobody to put in a main trap at the wall, and the connection runs right through to the top of the house. We had considerable difficulty with the United States Government, which insisted on putting a trap on their post-office, but they didn't do it. Their specifications called for it, and as a usual thing they do it. They also wanted to put in a 6-inch connection. We have never had any trouble with this system of ventilation. A great many people think there is danger from it, but I don't think so. I cannot see any need to have holes in the manhole covers where this system is used. Of course the question might be raised as to how the air gets into the sewer. I think the elevation of the houses, in a great many cases of 100 feet, would act as a chimney, so that in certain places air would be going down in the sewers, and other places coming up. I hope somebody will make experiments on that and see where the air goes in and out, and whether it goes in during certain weather conditions and out at other. Perhaps it doesn't ventilate at all.

Mr. Woodfall.—I can say that one experiment showed that with open covers in some manholes the air was going downward through the holes and in others coming out.

Mr. Felton.—I presume that would be so.

Mr. W. C. Parmley.*—I did not come here with the intention of saying anything, but to hear the rest talk and learn something myself, and so all that I will say is what comes to me on the spur of the moment, but it may be possible for me to bring out some points.

Mr. Felton has spoken entirely of the separate system of sewers. In connection with the sewerage of Cleveland I have to speak of the combined system. The problem of maintenance, of course, is entirely different in a combined system than it is with the separate system. The first serious difficulty which I discovered in Cleveland was in the management of sewer maintenance. The work was in charge of the street department, and the city engineer had no authority. The result was that no attention was given to the sewers until a stoppage occurred and complaint was made, and then when they got time a gang of men would be sent to remove the obstruction. The result was that some sewers would go for years without

* Formerly City Engineer, Cleveland, Ohio.

cleaning, and others, under more fortunate circumstances, would be cleaned oftener. There were upwards of 8000 catch basins at that time, and their chronic condition was that they were filled up to the level of the outflow pipe, and received no attention, except when complete stoppage occurred. Some two or three years ago I undertook to remedy those conditions, and started an agitation along that line. Some of the results of my investigation were published in the JOURNAL of our Society.* The recommendations I made at the time were not all carried out, but most of them were, and they worked very satisfactorily.

The first thing we did was to take the matter entirely out of the street department's hands and place it under the control of the city engineer. We made the sewer department a division of the city engineer's office, and placed in charge an assistant engineer who was a man not only qualified from an engineering standpoint, but also of good executive ability, qualified to manage men, and to keep accounts.

The work was organized with several different gangs of cleaners and inspectors, provided with the necessary tools, wagons, carts and poles, and the city was gone over in a systematic manner. The sewers were first inspected, and where found to be in an unsanitary condition the gang of cleaners began work and followed it down to the outlet. In this way the entire city was covered. When the entire system had been inspected and cleaned the circuit was begun again.

The city is divided into upwards of twenty different sewer districts. The drainage lines do not entirely conform to these districts, as in some cases one sewerage system runs into three or four different sewer districts. Hence one of the first difficulties encountered was in the distribution of the cost of maintenance.

The question was solved in rather an ingenious way. As it happened, some of the sewer districts were not only in a badly dilapidated condition, but verging on bankruptcy, while other sewer districts were just the other way, having at all times a large sewer fund. Sewer district No. 3 was made a clearing house for all the other sewer districts, and all the cost was charged directly to this one sewer district, and once a year the proportional amount chargeable to each sewer district was charged to that district and credited up to district No. 3, which was footing the bill, and in that way it made the accounting system very simple.

A portion of the city is much more sandy than other portions, and in those portions a great deal of cleaning is necessary, espe-

* JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, June, 1900.

cially from the fact that the sewers in many cases have flat grades. Frequently heavy storms wash much sand into the sewers in the districts in which the streets are not all paved. Under these circumstances it has sometimes been necessary to go into the sewers, and with shovels actually shovel out the sand. In other cases, the ordinary methods of flushing have been successful.

One of the most difficult and beneficial acts accomplished by the city has been the transfer of this control of the sewers from the street department,—itself controlled by politics,—to the engineering department, where the benefit of clean sewers is appreciated, and where it is not so much a matter of politics. The result is that the work has been very much better done than it was formerly by the street department cleaners.

Mr. W. D. Hubbard.*—We have in Concord a separate system of sewers, composed almost entirely of vitrified pipe, from six inches to twelve inches in diameter. Our mileage at present is 7.53 miles, and there are 143 manholes. The system has been in operation only four years. We have not had a single case of stoppage so far, in the street sewers, but we have had trouble from tree roots in the streets which are lined with trees.

From what we have been able to discover, if there is a joint in the sewers in which there is a hole as large as a knitting needle, the root will get in, and will grow from ten to fifteen feet long. We remove them with an ordinary wire brush made up of thin strips of flexible steel, which is drawn through the sewers with a ¾-inch Manila rope. This brush tears off the root where it enters from the joint, and brings out the whole accumulation of branches at the manhole. We have tried some of the patented devices for cleaning sewers, but from what little experience we have had, I think the brush gives the best satisfaction.

Our present method is to clean the entire sewer once a year. We use the ordinary Boston rod, the first rod being connected with a ball of iron two inches in diameter, which breaks up and dislodges any ordinary accumulations of rags or silt. At the end (at the manhole) we attach a ¾-inch Manila rope, and on that we put a wire brush, with another small rope attached to it, so that in case we should lose any part of the apparatus we may recover the lost article. We start that way at higher levels and work through to the lowest levels, taking out all accumulations of rags and silt.

The cost for the first year of cleaning the dust pans, which are cleaned once in the spring and once in the fall, and brushing out the entire system of sewers, was $175.50. That included the

* Superintendent of Sewers, Concord, Mass.

time of the men who were actually employed, and the amount that we paid for horse hire, the horse being used to cart around a barrel, in which we put the accumulation, so as not to put it on the surface of the street.

The grades that we have at Concord are, for the 6-inch street sewers, one per cent.; on the 8 and 10-inch sewers, 0.5 of one per cent.; for the 12-inch sewers, .15 of one per cent.

The house connections are all 5-inch, and the minimum grade adopted was about 2 per cent. In one case we had a building that was quite a distance from the street, so that we were obliged to use a flatter grade, say a grade of $1\frac{1}{2}$ per cent., with an angular turn inside a manhole. I watched that connection with particular interest to see just what condition that line would be in, and I would say that that is the cleanest house connection in town. The house connections laid on steep inclines are often fouler than those upon flatter grades, as the liquid runs away and leaves the solids adhering to the interior of the sewer pipe.

The construction of the sewerage system was begun in 1898, stopped in the winter, and resumed again in 1899, and the sewers that were laid in 1898 were used as drains during the construction of parts of the system laid in 1899. The result was that a considerable amount of sand accumulated in some of the lines. We had one 8-inch line which was filled with sand for a distance of 580 feet, and the problem was how to get rid of the sand. We tried scrapers attached to the Boston rod, and they operated very well up to a distance of 25 or 30 feet from the manhole, but after we got in 50 or 60 feet, the scraper would simply run up hard against the sand and stay there, and when we pulled it back we wouldn't have anything to show for our trouble. So we ran the rods through the entire distance between manholes, carried a rope through, put a chain about 3 feet long in the middle of the rope, tied knots in the chain, turned a hydrant stream into the upper manhole and pulled the rope back and forth, dragging the chain over the sand. The only result we got from that was to distribute the sand over twice the distance. Then we put a plug in the lower manhole and repeated the operation, using an Edson pump to pump out the sand and water. That brought it out, but it looked as though it was an everlasting job to get the sewer cleaned that way, hence the next step was to get an ordinary piece of stove pipe, somewhat smaller than the sewer, and $2\frac{1}{2}$ feet long, and put a plug in one end in such a manner that there was a space of about a quarter of an inch around it, in order that any water in the pipe would run through and leave the sand. We attached this pipe to the rope and pulled

it as far as we could, and then pulled it back bringing some of the sand with it. In this way we cleared the sewer. Since then we haven't had any trouble with sand. More or less sifts through the covers, but as I previously said, we have dust pans under the covers that retain all save the finest.

In the house connections we have possibly three or four stoppages a year, and they seem to be principally caused by newspaper and coarse wrapping paper, which lodges in the pipe.

We had some little experience with patent scrapers intended to be attached to the Boston rod, but it was very disastrous. The first time we attempted to use them was in 1900. We had everything going smoothly until we got into a section of sewer work in which the manholes were 375 feet apart. The scraper stuck somewhere and the rods broke, and we had a scraper and about 100 feet of rods left in the sewer. We made numerous attempts to get the rods out and dislodge the scraper, without any effect, and finally the sewer had to be uncovered and a hole cut in the pipe. The scraper has stayed out ever since.

In regard to the flushing, the dead ends of the system are provided with automatic flushing tanks that contain 320 gallons, the intention being to operate them once a day. From what I have noticed in regard to these flushing tanks, I can only say that they are effective for perhaps 500 feet. If you pass two manhole distances the friction in the sewer reduces the flow or velocity so that the water from the flushing tank does not run over an inch or two inches deep.

On the high levels where there is no flushing tank, we simply take a plug made of sheet rubber, backed with canvas, and packed between two circular pieces of wood about half an inch less diameter than the pipe, and push it right into the pipe. We fill the manhole from the nearest hydrant, pull out the plug and let a charge of water from the manhole go down. This we do twice a year, spring and fall, and we have never had any complaints from odors, either from house connections or from the street manholes.

After hearing the gentleman from Waltham mention the cost of cleaning, I am a little loth to say what the cost is at Concord, though the small mileage of sewers tends to increase the rate. Its average for the past three years has been from $20 to $25 a mile a year. With the present methods the lines are kept free from roots, the liability of stoppage reduced to a minimum, and I do not think it would be of advantage to reduce the cost very much and then have stoppages which would cost more than we save.

I might add that after having the Manila rope break two

or three times we bought a piece of what is known as "tiller" rope; this is made of a number of fine strands of wire inclosing a hard core. It was very strong and very flexible, but we found that unless the men are very careful to keep it from touching the ends of the pipes at the manholes, the sawing back and forth, when the brush is in motion, will cut through the pipe in very short order. Then, again, the small wires are apt to break, and when they break, the rope becomes rather awkward to handle and cuts the men's hands.

MR. DANA LIBBY.*—As most of you probably know, the city of Newton covers a large area, its greatest length from north to south being 4½ miles and its greatest width 4¼ miles. It is composed of fifteen villages, of which the part known as Newton Corner is the nearest to Boston,—seven miles from the South Station.

Owing to the fact that the population covers so large an area, long trunk lines and many miles of small pipe sewers laid on minimum grades are necessary and the maintenance expense is necessarily larger than in most cities of the same population.

Newton has what is known as a separate system, consequently most of the sewers are small. The first contract was let in the spring of 1891, and we have at present 96 miles of sewers, 80 miles of which are 8-inch pipe; 8-inch is practically the minimum size, 6-inch having been laid only in a very few short streets where the rate of fall was large. The minimum grade used here for 8-inch pipe is 0.50 per 100 feet. The sizes used for house connections are 5-inch and 6-inch, with a minimum rate of 2 feet per 100 feet. The trunk lines are 24 inches by 36 inches and 20 inches by 30 inches, egg-shaped.

Underdrains have been laid under the sewers in all cases where ground water was known to stand near sewer grade. This gives a dry foundation on which to lay the sewer, and assists in taking water from damp cellars.

Two men with a three-wheeled push-cart attend to the flushing of the sewers through the year, covering the whole system in from four to five weeks. Flushing-manholes with a 1½-inch connection to the water main are built at the summits and ends of lines. Rubber-bound wooden plugs are made of the right size to fit the outlet. When the outlets have been plugged, the manhole is filled with water and the plug is drawn. This sudden flush of water is usually sufficient to clean a line throughout its entire length. If, however, any solids are found farther down the line, a second manhole is filled from the same flusher and the operation is repeated.

* Deputy Street Commissioner in charge of Sewers, Newton, Mass.

The flushing gang are instructed to begin at the outlet and follow up the line, taking off each cover as they go. If the line is found to be clean, the flushing is omitted. This flushing gang also attends to the numerous stoppages which occur on house connections, as well as to the ordinary flushing and cleaning. During the winter months, when the sewer construction gangs are not busy, an additional force is employed in cleaning places that need immediate attention, these places having been determined beforehand by mirror inspection.

The streets of Newton are lined with shade trees, and their roots readily follow down through the less compact earth in the sewer trench and find defective joints if any exist. The underdrains become clogged with these roots much more frequently than the sewers, as they are laid with open joints, but the number of stoppages in sewer pipe, due to an accumulation of roots, has been far greater than was ever anticipated. Our maintenance appropriation for one year is not large enough to enable us to dig up and relay these bad places, and for a long time we have been trying different kinds of apparatus with which to successfully remove these roots. On the accompanying print will be seen the sewer cleaning implements in use in Newton. The spring-cutter shown on the upper part of the sheet has been in use only two seasons, but has proved to be a very effective root-cutter. Two positions are shown to better illustrate its use. This cutter is made of the best American spring steel, $\frac{1}{4}$ inch thick, and about $\frac{3}{4}$ inch wide, with the outer edge sharp like a knife. The ends of the spring being small, are easily pulled into a bunch of roots; and the cutting action, caused by pulling the spring backward and forward, is sufficient to loosen a very compact mass. This device has also been found to be useful in removing grease and silt which collects on the bottom and sides of sewer pipe.

For the last two years, the city of Newton has used only the deep-socket pipe in three-foot lengths for sewers, and we consider this one of the wisest steps taken for securing tight joints.

Up to the present time we have found no especial difficulty in the maintenance of iron inverted siphons. The 6-inch and 8-inch double inverted siphon under the Charles River at Newton Upper Falls, which the city built in 1901, has given no trouble worthy of mention. We have three other 6-inch inverted siphons in the city which are usually cleaned every winter, but have been allowed to go two years without causing any trouble.

The large trunk lines are kept free from deposits by a system of

hand cleaning and the use of the car and scraper on the print. This work costs about $80 per mile.

The total cost of flushing and cleaning pipe sewers in Newton for the year 1903 was $1791.67 or $19.08 per mile.

Mr. E. S. Dorr.*—Mr. President and gentlemen: I doubt whether I can offer you anything that is of any value. The city of Boston has no separate system of sewers. Nearly all of our sewers take street water through catch basins, and our difficulties of maintenance come from that source. Most of our stoppages in sewers are caused by gravel and sand being carried over from the catch basins into the sewers. This of course would not happen if the catch basins could be kept clean down below the trap, as they should be. It unfortunately happens that the sewer department has had an insufficient amount of maintenance money now for many years, and the condition of the catch basins and of the sewers is quite similar to that in Cleveland described by Mr. Parmley.

In flushing sewers we use, almost altogether, the fire hose connected with a hydrant. In old times we had some flushing manholes constructed at the upper termini, which were filled with water and emptied as has been described by the other speakers, but that is very seldom done now. There are no flushing tanks in use in the city of Boston. When flushing proves insufficient, we resort to cleaning by scrapers. We have the ordinary outfit of jointed rods and hoe scrapers. The rods we use are the rods which screw together with threaded couplings. There is another form on the market with the toggle-joint, but I advise you to beware of it, because it lacks the rigidity of the rod which screws together, and it is also impossible to do with it what can be done with the other. When the hoe scraper catches, as Mr. Hubbard has mentioned, it is almost always in a defective joint. With the screw connected rods, the rods are turned in the right direction, so as not to unscrew them, and almost always the scraper can be turned on its back and thus released.

We find almost all kinds of material in the sewers. In some sewers the material packs down very hard indeed, and for these sewers we have in the last three or four years made considerable use of a patented device, of which, with your permission, I will proceed to show you a model.

This first came to our notice when we had a sewer in East Boston which was almost stopped up with the East Boston hard pan. Our foreman was entirely unable to remove it with the ordinary scrapers, but a man named Healy made his appearance and asked for a chance to try it. We gave him the opportunity, and he pro-

* Chief Engineer, sewer department, Boston, Mass.

ceeded to put his machine to work, and he cleaned the sewer. Since that time we have given him other difficult sewers to clean, and, as a matter of fact, it has become almost a practice to delegate to Mr. Healy sewers which are pretty difficult to clean. The machine is essentially a shovel or scoop carried on a truck and supported on three wheels. It is sometimes used in connection with a jointed rod or a rope can be attached to each end, and it is then worked by winches from the manholes at each end of the stretch which is being cleaned. That device has proved very effective. The illustration shows the manner of pulling the device back and forth by means of winches. I think the peculiar advantage of that is in the rope, by which the operator is enabled to trip the scoop, in case it catches, and in that way free it.

The Chairman.—How small a sewer will that work in?

Mr. Dorr.—That will work in a 12-inch sewer. There are various sizes.

The Chairman.—How large?

Mr. Dorr.—I think he said they had them for four-foot sewers.

The Chairman.—Different sizes?

Mr. Dorr.—Different sizes. In brick sewers, I know he sometimes runs through a small one, when the sewer is nearly full, and then follows it with a larger one. This particular job in East Boston which he first undertook cost 17½ cents per running foot. The material was packed down almost to the hardness of concrete, so that shortly before that we had to take up and relay a 12-inch sewer.

While I am on that subject I might mention the fact that we have had considerable trouble in Boston from marble and glass dust from factories where those materials are worked. In one case we compelled the parties to put in a catch basin, the essential feature of which is that the outlet is placed at a higher elevation than the inlet, so that if the catch basin is not kept clean it disconnects itself so that it must be kept clean.

Now, in regard to siphons, of course what I have to say applies both to siphons on combined sewers, and on intercepting sewers. The largest siphon the city has is in Dorchester Bay. That is a 7½-foot brick siphon and dips down about 160 feet and comes across Dorchester Bay to Squantum. No difficulty has been experienced in maintaining this sewer except from accumulations of grease in the shaft at the outlet end of the siphon, and that is rather an annoyance than anything else.

That has amounted to as much as 25 cubic yards per month. At the present time it is taken care of by a party who clarifies and makes some use of it. I don't know what, I have never inquired.

But we give him the grease if he will keep the shaft clear, and that has been a very good bargain. We guard, of course, very carefully against letting any heavy deposits go into this sewer by running the sewage through two deposit sewers. The sewage is passed through one of these sewers at a slight velocity so that settlement may take place, and when several feet of this has collected, the sewage is run into the other one, and the first one is cleaned. These sewers are 16 feet wide and about 1600 feet long. It is quite a task to move this mass of material down to the lower end from which it is removed, and two crude devices, which may be of interest, have been used. One is floated on a pontoon, from which depends a vertical diaphragm like a large barn door. The sewage supports the pontoon, and running underneath the diaphragm, which nearly fits the sewer, carries along the sludge.

The Chairman.—That is a float in the chamber?

Mr. Dorr.—That is a float in the chamber. A rather more effective device is shown here. This is a submerged raft with a vertical diaphragm standing on it. It is a little more effective, but stirs up the material more than the first one, so this one is usually in the inlet end, the upper part of the deposit sewer, and then the one depending from the pontoon is used on the end next to the shaft, so as to create less disturbance, and causes that material to be carried over into the shaft. When this matter is moved, to a point near the west shaft where the tunnel begins, it is taken hold of by a conveyor, so-called, which is a kind of rough elevator pocket arrangement which scrapes the material along to the outlet of the pipe, when it is flushed down into a tank and deposited from the tank into scows and taken to sea.

I have another blue print here showing the detail of a siphon of the Dorchester intercepting sewer. Very little difficulty is encountered on siphons in intercepting sewers for the reason that the flow is large and very fairly uniform, and they keep themselves clean. In this manner there has been no trouble whatever, except a slight accumulation of grease, which is taken care of by the same individual who takes care of the other.

But the siphon on a combined sewer, which receives the flow of many catch basins, is a very different proposition. I have here a blue print of a very small form, and I offer it as a good example of a bad design. That siphon is situated on Tremont Street, at the foot of Calumet Street, at the foot of a very steep hill, and it has been the source of great trouble on account of the impossibility of keeping it free from deposits of sand and gravel. It has to be cleaned out, and it has to be visited at regular intervals lest

it may become stopped in the meantime. The deposit, of course, occurs at the time of low flow, and is not noticed until a storm comes along, and then the siphon is found to be insufficient in size, and backing up and flooding result.

There are some other siphons in the Boston system, of which I don't happen to have the plans. We have a very troublesome one on Hanover Street, caused by the putting of the subway down Washington Street. The peculiarity of this siphon was that it became plugged with grease from the hotel district drained by the Hanover Street sewer, and we finally adopted a system of having this inspected once a week and cleaned out once every two weeks, and that is the only way in which we could keep that clean. That has now been happily relieved by the building of a deep sewer, which drains off the lower end of it, and practically removes the siphon. But that was the system which we had to adopt.

The best form of siphon which I know for a combined sewer is the kind we have to-day. It is a double-pipe siphon. The ordinary dry flow being conducted through the smaller of the two pipes, and the larger one being available for carrying the storm flow. I have here two blue prints showing the details of such construction. Several of these have been built, particularly in Brighton, and they give almost no trouble. They practically keep themselves clean, the velocity in the small pipes being sufficient to keep them cleaned, and no flow occurring in the large pipes, except at the time of storms. A cleaning of once a year is sufficient for them. That is all that occurs to me to say on this subject.

Mr. F. Herbert Snow.*—The difference of cost of operating and maintaining a properly designed and constructed separate sewer system, and one not so designed and constructed, is illustrated by a comparison of the figures which have been given to-night with those which are about to be offered.

The data for the latter were collected in a city outside of Massachusetts, in which there are over 40 miles of separate sewers and as many more miles of house connections. About one-half of the sewers and connections are said to have been laid within the past ten years, and about all of them were constructed in a desultory manner, regardless of a comprehensive plan. The name of the city is withheld pending the submission of a report to the authorities on the subject.

In this city over $4000 was expended during the last year in scooping out sand and removing stoppages from the sewers. To facilitate comparison, the expense may be divided into three classes:

* Civil Engineer, Boston, Mass.

1st. Inside stoppages—those on private property.

2d. Stoppages in connections—outside of private property.

3d. Those in street mains.

The cost of the inside stoppages is assumed by the private owner.

The last two divisions pertain to the expense of maintaining the public system.

Considering now ordinary stoppages only, we have the following items of cost for the year, for each division:

Inside stoppages	$145
Connections	596
Mains	1,063
	$1,802

The $145 represents the money expended by the public office in locating stoppages which were reported to be in the house connections in the street but which, upon inspection, were found to be actually on the inside of the property and the subsequent removal of which therefore had to be attended to by the owner at his own cost. No record is kept of this private cost, but it is known to be large. The number of inside stoppages unreported is also known to be large, in fact, several times greater than the number reported.

During the year, in the street mains and connections, there were 482 ordinary stoppages and 134 more on private property, making a grand total of 616 stoppages chargeable to the operating account of the sewer system.

In analyzing the causes of these stoppages it was found that

Grease	caused	19	stoppages in	mains and	8	in outside	connections.
Sand	"	25	"	"	26	"	"
Rags	"	83	"	"	47	"	"
Breaks	"	16	"	"	21	"	"
Misc.	"	79	"	"	128	"	"

The 222 stoppages in the mains, cost $1063, or $4.79 per stoppage.

The 260 stoppages in the outside connections, cost $594, or $2.28 per stoppage.

The total cost of each one of the above causes according to the classification in the table was as follows: grease $189, sand $208, rags $444, breaks $139, miscellaneous $677.

But most of the miscellaneous stoppages were caused by the accumulation of grease between the street line and the sewer main, and about one-half of the inside stoppages originated from this source. So also grease materially increased the cost of scooping

out the sewers. In view of these facts $1200 is estimated to be the annual expense of handling the grease trouble, but this represents only the money paid out for the removal of grease from the public sewers and connections. The annual sum paid out by individual owners for inside grease stoppages is estimated to be not less than $3500, which represents an investment at 4 per cent. of $87,000 or about ten dollars for each connection in the city. While this is a large sum, it would require over $200,000 in the aggregate to install a proper grease trap in every building connected with the sewer system.

The inconvenience and unhealthfulness of frequent stoppages is, however, a matter of serious importance and demands some remedy. About 300 stoppages annually are attributable to grease. These might be prevented by the installation of proper apparatus on every property.

The cost of handling the sand for the year was as follows:

In inside connections	$75
In outside connections	121
In mains	227
	$423
Scooping in mains	741
Total	$1,164

The sand enters through defective joints and broken pipe and through house connections. Quite frequently it comes from the inside property and runs out through the connection and fills the street sewer.

In conclusion it seems fitting to observe that only a very brief comment on these figures is called for.

The annual cost of operating and maintaining the separate system in most cities does not begin to approach anywhere near the above amounts, and as would be expected the excessive cost in this case is due to abnormal local conditions, which, it may be added with emphasis, might have been avoided and no doubt would have been had the present state of affairs been foreseen or anticipated.

The various items cited are so great as to forcibly illustrate the economy of devoting attention to the design and construction of house connections as well as to the sewers themselves.

In fact, the sewer system begins in the house and if a division is made between the public sewers and the individual house connections whereby care is exercised in laying out and building the former, and the latter are allowed to be laid and maintained without such care, the whole sewer system may be rendered inefficient and unsanitary.

Mr. W. D. Hunter.*—Melrose is situated seven miles north of Boston, on the Western Division of the Boston and Maine Railroad, and has a population of about 14,000 people, located in three settlements,—Wyoming, Melrose and Melrose Highlands.

The sewer system, which is a separate one, serves about 13,000 people, comprises 35 miles of pipes varying in size from 6 to 24 inches, and cost $390,000. In its construction, every effort was made and no expense spared to make it as efficient and lasting as possible. All pipes used were of a special design, deep and wide sockets, molded in 3-foot lengths, and selected with great care in regard to regularity of form, smoothness and glazing; all joints were made and all brick work laid with Portland cement mortar; manholes were located at all junctions, all changes in either line or grade, and at intermediate points 250 feet apart, although in a few instances the distance between is 300 feet. The work was begun in 1894, and practically completed in 1898, although each year since then minor extensions have been made.

Melrose is situated in a valley, surrounded by hills, and consequently many of our sewers are constructed on a flat grade, and nearly all are below the ground water of the territory; fully two-thirds of them required underdrains which were for temporary purposes only. Underdrains with permanent outlets were tried and found unsatisfactory.

The sewers constructed during the years 1894 and 1895 were provided with automatic flushing tanks located at all summits, connected with the water mains, and the flow so regulated that they would dump once a day or as often as required. Upon trial it was found that the benefit from these tanks was purely local and did not extend more than 300 or 500 feet; consequently their use was discontinued.

All house connections are 5 inches in diameter, laid by the city accurately to line and grade; and where angles are unavoidable, manholes are required. The connection with the house plumbing is made through a Y, and the opening directly in the line of the pipe provided with a screw-cap, which can be removed for flushing or cleaning. The Board of Health require the use of the running trap, but if the householder desires to omit it, he can do so by having his plumbing made to stand the water test. Few have done this, therefore it cannot be said that our system ventilates entirely through the houses, although it does so to some extent, but principally through the manhole covers, each of which is perforated with four

* Engineer and Superintendent Public Works, Melrose, Mass.

$\frac{3}{4}$-inch holes. This is apparently satisfactory, as we have had no complaint nor been visited by an epidemic of any sort; in fact, Melrose is one of the healthiest places in the Commonwealth.

In regard to flushing or cleaning, I hardly think that flushing is the proper word to use for the work done by us in cleaning our sewers, as we rarely use water other than that flowing in the sewers.

I have read the papers presented at the last meeting, and find that the method of cleaning in Melrose differs from that used in any other place mentioned, and I presume this is largely due to the different conditions that appear to exist.

Most of the papers refer to trouble or bother by stoppages from tree roots; although the streets of Melrose are lined with trees to such an extent that from a distance it has the appearance of a forest, this complaint is practically unknown to us. We have had only two stoppages from roots, one in a main pipe and one in a house connection, each of which was readily removed, as the root which entered the joint, and which connected the growth inside the sewer with the main root outside, was very small, not more than 1/16 of an inch in diameter, and broke easily when hooked onto. The accumulation of grease is prevented by the use of extra large "pot traps," located at the inlet of each fixture; these traps also act as grease traps.

The method pursued in cleaning the sewers is to scrape out any deposit that may have lodged in the inverts. We start at the summit and flush or clean all laterals to the main and then clean the mains, and so on, sweeping everything down to the sump where our local sewer connects with the Metropolitan sewer, and where any deposit can be readily removed. The cleaning or scraping is done by a steel hoe made the shape of the pipe with a joint or hinge, so that in pushing it backwards it partly collapses or shuts up. Back of this hoe is what we call a follower, which consists of a bag or bundle of bags, made into a roll two or three feet long and wound with a small rope so as to entirely fill the smaller pipes, and is drawn through after the hoe; this also stops the flow of water, and when the hoe is pulled out into the manhole the deposit is taken up in pails, carried to the surface and put into cesspool barrels. When the follower is pulled through into the manhole, there is a rush of sewage or water which sweeps them clean.

This method is of course much more expensive than the ordinary use of a hydrant hose, which we also use in some places. The same process is followed in the larger pipes, except that the bag or follower does not entirely fill the sewer, perhaps only two-thirds, and is kept on the bottom by being weighted or filled with sand.

We use the so-called Boston rod, extra heavy castings fitted with oak rod 1½ inches in diameter and 3½ feet long, made especially for us, and have never had any trouble with their breaking or coming apart.

Our cleaning is done once a year, usually in the winter, when the men employed would otherwise be idle.

The cost of flushing or cleaning a system of sewers depends largely upon its situation and method of construction. We have no siphons; all of our sewers have a continuous grade from summits to outlet, and cost us yearly to clean about $600, or $17 per mile, including labor, teams and all incidental expense.

Mr. T. Howard Barnes.—I would suggest, Mr. Chairman, that there should be a statement incorporated with this paper describing the flushing tanks in use in Melrose. I think it is misleading that they should be described as flushing tanks. As a matter of fact, they are tilting tanks holding about 50 gallons each and not the siphon tanks which discharge 200 or 300 gallons.

Mr. Berry.—I should like to inquire if the result would not be just the same with the siphon tank. In Laconia, N. H., we use siphon tanks and my experience has been that although our tanks hold 150 gallons, we do not get any different results from those in Melrose. If better results are obtained anywhere, I would like to know it.

Mr. Harrison P. Eddy.*—The sewer system of Worcester comprises 169.13 miles of sewers, 6380 manholes and 2630 catch basins. About 450 house connections are made annually. There are now 68.9 miles of sewers for sewage only, 61.64 miles of combined sewers and 38.66 miles of surface water drains. For nearly twenty-five years the sewers have been built by day's labor, about 130 miles having been constructed in this way. At the present time the minimum wage is $1.85 per day of eight hours.

The following table gives the number of miles of sewers, the total cost and cost per mile of maintaining the same for each year from 1877 to 1903 inclusive. The lowest cost per mile reached in any year was $110.47 for 1898. During the last few years a number of automatic storm gates and pumping stations have been added to the system, and these have materially increased the cost of maintenance:

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* Superintendent of Sewers, Worcester, Mass.

COST OF MAINTAINING AND SIZE OF SEWER SYSTEM.

Date.	Miles of Sewers.	Net Expense.	Cost per Mile.
1877	36.17	$7,775.44	$214.97
1878	37.26	6,567.59	176.26
1879	37.38	6,307.16	168.73
1880	37.88	6,937.43	183.14
1881	40.40	6,379.10	157.90
1882	42.90	7,490.01	174.59
1883	45.63	8,421.88	184.56
1884	48.00	9,132.05	190.25
1885	50.94	8,656.86	169.94
1886	56.41	10,843.23	192.22
1887	62.89	12,819.53	203.84
1888	68.02	12,989.12	190.96
1889	71.39	13,995.65	196.04
1890	76.59	14,686.38	191.75
1891	80.94	13,435.66	165.99
1892	85.44	13,488.24	157.86
1893	90.04	15,423,38	171.29
1894	95.42	16,302.97	170.85
1895	99.29	17,518.17	176.43
1896	102.69	15,925.38	155.08
1897	112.01	14,504,06	129.48
1898	121.97	13,475.08	110.47
1899	134.14	16.234.00	121.02
1900	151.09	19,488.55	128.98
1901	158.47	19,730.69	124.50
1902	162.75	22,715.75	139.57
1903	169.13	26,300.89	155.51

During 1903 the entire cost of cleaning sewers was $9018.92 or $53.32 per mile. This includes the cost of a large amount of scraping, pail and boat work on sewers receiving storm water.

The cost of cleaning catch basins during 1903 was $8414.03, which amounts to $3.232 per catch basin per year. From these basins about 20,653 cubic yards of refuse were removed and hauled to the public dumps at a cost of $0.407 per cubic yard. This cost includes the entire expense of this branch of the work such as inspection, office expenses, thawing frozen traps and various incidentals but does not include repairs upon the basins themselves.

There are several methods of flushing in use, although all new work is provided with water pipes in the end manholes. There are several automatic flush tanks in use, although it requires as much care to keep them in good order as it does to flush from the pipes in the manholes, and so far as can be seen no better results are obtained. A large portion of the system is flushed at intervals of five

weeks with $2\frac{1}{2}$-inch fire hose attached to hydrants. This is a very expensive and clumsy method and has the decided disadvantage of not being practical in the winter, it not being deemed wise to open the hydrants for this purpose between the first of December and the first of April.

The minimum size of pipe used for public sewers is eight inches in diameter, and some of it is laid at a grade of 1 in 400, and no trouble is experienced with it. In fact in the last twelve years there have not been six complete stoppages in the sewer system and one of these was in a twenty-inch pipe. There has not been a single stoppage due to roots of trees, although there are many streets which are lined with old elms. Systematic inspections of the entire system are made twice each year and frequent inspections are made of certain doubtful lines of pipe. The entire maintenance department is in the hands of one man, who has no other duties than to see to it that no one complains of a failure to operate, either of a sewer or a catch basin. How this is to be accomplished is up to him to find out.

Eternal vigilance is the price of clean sewers.

Worcester is situated among hills, and there are many streets which have considerable grade with a resulting large quantity of detritus washed from them by every rain. Much of this finds its way into the sewers, although every inlet is provided with a catch basin. It is interesting in connection with a study of the problems of maintenance and cleaning to consider the reasons for these deposits.

The solid matter reaching the sewer will be carried along by the water and the pipe left clean provided there is sufficient current. Dubuat has shown that the velocity required varies for matters of different sizes; *e. g.*, 0.4 feet per second will move fine clay, while 2.5 feet per second will be required for fairly coarse gravel. It is obvious also that it will take a higher velocity to start an obstacle than to keep it moving.

It is generally considered wise to provide a grade sufficient to cause a velocity of 2.5 feet per second, when flowing full, although a great many sewers receiving storm water have been built on flatter grades. It is not enough, however, to provide a certain mean velocity and assume that there will be no deposit. At all points below half full the mean velocity will not be reached. From the following table it will be seen that the mean velocity in a 15-inch circular pipe laid at a grade of about 3.5 feet per 1000 feet is very low for depths up to five or six inches. It frequently happens that a storm will not reach an intensity sufficient to more than one-third fill the sewers. It also frequently happens that a certain part of the

shed intended to be served by the sewer in question is not developed, and for this reason the sewer does not receive even in storms of high intensity sufficient water to fill it more than say one-third full. Under these conditions and especially the latter it is easy to see why it is that there are deposits in the sewers even though they be laid at a grade which would give a velocity of 2.5 feet per second when running full.

MEAN VELOCITY AND DISCHARGE OF 15-INCH SEWER.

Coefficient of Roughness, 0.015. Slope, 0.0035346.

Depth of Water, Inches.	Mean Velocity, Feet per Second.	Discharge, Cubic Feet per Second.
1	0.60	0.021
2	1.05	0.102
3	1.43	0.250
4	1.74	0.457
5	2.02	0.723
6	2.25	1.031
7	2.45	1.375
8	2.61	1.737
9	2.74	2.106
10	2.84	2.468
11	2.91	2.807
12	2.94	3.094
13	2.93	3.311
14	2.85	3.397
15	2.53	3.105

In general the statements made regarding the storm sewers are applicable to the sewers for sewage only. There is, however, a difference in the matter carried in the water. In sewage the solids are largely of an organic nature and are nearer the specific gravity of the water in which they are carried. If deposits occur there is at once a fermentation started which disintegrates the larger solids until they reach a size easily carried along. If this decomposition goes far enough there will be gases formed which will actually lift this matter to the surface of the water when it is readily washed onward.

Following is a table in which the interesting features of two lines of surface water sewers are presented. In different portions of each sewer trouble is caused by deposits forming.

Street.	Location.	Kind.	Size, Inches.	Length, Feet.	Grade per 1000 Feet.	Velocity, Feet per Second.	Shape.	
Pink	John to Highland	Surface	24x36	81.2	0.95	2.06	Egg	Deposit occurs.
"	"	"	18	132.9	0.99	1.47	"	"
"	"	"	"	112.0	0.97	1.46	"	"
"	"	"	"	106.1	0.62	1.17	"	"
"	"	"	"	131.8	3.69	2.86	"	"
"	"	"	"	114.0	0.58	1.13	"	"
"	"	"	"	117.25	2.08	2.14	"	"
Highland	Pink to Schussler Rd.	"	"	21.0	6.33	3.74	"	No Deposit
"	"	"	"	183.0	4.12	3.02	"	"
"	"	"	12	165.6	4.07	2.26	Rd.	"
North	Grove to Milton	Combined	22x33	453.5	1.00	1.99	Egg	Deposit occurs.
"	Milton to Prescott	"	18	125.5	1.70	1.94	"	No Deposit
"	"	"	"	125.3	2.29	2.25	"	"
"	"	"	"	125.0	1.34	1.72	"	"
"	"	"	"	118.9	3.08	2.61	"	"
"	"	"	15	127.6	4.18	2.56	"	"
"	"	"	"	125.0	1.51	1.54	"	"
"	"	"	12	125.3	17.08	4.63	Rd.	"
"	"	"	"	125.4	38.80	6.97	"	"

In this table the figures are given beginning at the lower end of the sewer and proceeding up the line. It will be noticed that there is no trouble with the Pink and Highland Street sewer at the upper end nor until a point is reached at which the velocity falls to 2.14 feet per second. There is one short section of this sewer where the velocity should be 2.86 feet per second and where trouble is experienced, but it will be noticed that there are very flat sections on each end of this one which doubtless have an effect upon the steeper portion.

It is interesting to notice that there is no trouble with the North Street sewer until the lower end is reached where for a distance of about 450 feet the velocity falls to 1.99 feet per second. This velocity is considerably higher than that of several sections above, where it falls as low as 1.54 feet per second in one case. It should be noticed, however, that each of these flat sections is preceded by at least one section which has a good velocity. It therefore seems reasonable to assume that the velocity resulting from the steeper grades has an effect upon the short sections immediately below and in this way the detritus is carried by the short, flat portions.

These tables and conclusions are of course very incomplete and of a tentative nature, but it would seem that further study along

these lines might result in the accumulation of information which would prove of value.

The Chairman.—I would like to ask Mr. Eddy what his flattest grades are on separate sewers?

Mr. Eddy.—We have flat sections on sewers of about every size, but I would not dare to tell from memory what the flattest grades are.

The Chairman.—In Cambridge we have a number of sewers laid on very flat grades both in the combined and in the separate systems. One trunk line of combined sewer, of sizes 4 to 8 inches in diameter and about 6000 feet long, is laid on a grade of .033 per cent. or 1 in 3000. This sewer, laid nearly 30 years ago, has required but little cleaning, although subject to tidal action which checks the flow twice a day, and would naturally cause a deposit of street washings, etc.

In 1895, a separate sewer was built, 1950 feet long, 24 inches in diameter, on a grade of .06 per cent. or 1 in 1666. Included in this was an inverted siphon 130 feet long under a canal.

In addition, about 3900 feet of sewer 25 x 29 inches in dimensions were built on a grade of .08 per cent. or 1 in 1250. Neither of these sewers has been cleaned, although the flow at times is very small. The sump at the siphon filled to a certain point, and has since remained with the same amount of deposit in it.

While it is desirable to lay sewers, especially laterals, with a good grade or inclination, my experience would indicate that extremely flat grades are not only permissible but practicable—the latter requiring simply more careful watching and more frequent flushing.

Mr. George A. Wetherbee.*—Mr. Brewer has related almost exactly our experience in Malden. We have about 47 miles of sewer, ranging from 6 inches in diameter to three feet. In regard to the flatter grades, quite a number of the sewers are from one in 450 to one in 500. A 15-inch sewer has a grade of one in 750; an 8-inch sewer, one in 900, and the 2-foot sewer, one in 1500. On the 15-inch line we have an inverted siphon, which we clean out once a year, and there is not very much in there then.

We have one 8-inch pipe in Edgeworth with a grade of one in 500. We take care of that at the annual cleaning in the winter and again in the summer. I think once or twice we have had to flush it in September and then again in June; but the other 8-inch sewers in that district have a grade of about one in 300, and we have had no difficulty with them. The cost of cleaning is a little less than

* City Engineer, Malden, Mass.

$5 per mile each year. We may have to pay more for it after a while.

About 2 years ago the State took a portion of our larger sewer in order to take care of some of the Everett sewers, and I don't think they have touched that sewer since they took it. It doesn't look as if they had.

THE CHAIRMAN.—How large is that sewer?

MR. WETHERBEE.—It is a three-foot sewer. About 3 years ago, we started to clean that as usual in the winter, and found the entire length of it, some 700 feet, covered with a thick crust or scum, so thick that if you dropped a rod upon it, it would bounce back. So we started to clean it by flushing at each of the manholes. I fitted the manholes with curbs so as to put in boards, and in the bottom one was an orifice, a little less than the diameter of the sewer, closed with a slide. The manhole was filled with sewage and flushed perhaps 20 times, and in the first manhole, 500 feet below, we did not notice any movement of the grease. I then borrowed from Mr. Barnes a jumbo—a series of rubber discs, 8 or 10 inches in diameter, and managed to get my rods and ropes through the manholes, and pulled that through without starting it at all. It was pretty cold weather, and we gave it up, thinking we would wait until warmer weather and then finish it. In the meantime I had prepared some wooden balls, a little less than the size of the sewer, and took them down about the first of June, and opened up the sewer and found about 5½ inches of water. The scum and everything else had gone. That stuff which was so thick and looked like a piece of carpet had during that time all disappeared.

In the small sewers I have the head of every line connected with the water pipes, by a 1½-inch service, and these manholes are filled at the annual cleaning. I have a tin form that I put into the sewer and when the manhole is full I pull the cover out of that, and in that way I flush the sewer. We have no flushing tanks, and I thought I would wait until I found somebody who would demonstrate the advantage of them. We never used a great deal of water. We have never had any roots in our sewer and never had but one stoppage, and that was in a 6-inch pipe on a grade, I think, of about 9 or 10 per cent.

In the house connections we have had one stoppage from roots, and I had at that time a chisel or a gouge made to cut the roots out. Since that time, we have never had any trouble from this source. When we first started putting in the house connections, the city contracted with some of the sewer layers to do the work and at that time we had one stoppage. One of the inspectors allowed the sewer

to be laid up to a rock about 5 or 6 feet in diameter, and instead of removing the rock he began on the other side. We found that out a little later and removed the rock.

I was pleased to hear Mr. Brewer say it cost so little to clean the sewer in Waltham. It does not cost me more than $5 a mile.

I think a good deal depends on the way sewers are laid in the first place. Ours were laid very carefully, and sometimes I think they may have been laid extravagantly. They are all as straight as a gun barrel and they are as clean as a new gun barrel when you look through them. I think that is really the secret of success.

Mr. Eddy was speaking of the grades of sewers. We have a great many flat ones, and I do not know why we don't have more trouble, but we certainly get along very well with a grade of one in 500. I have made plans for what we call the Linden district, and a great many of my 8-inch pipes have been projected by necessity, with grades of one in 800 and even one in 1100. I don't know whether we will have any trouble or not. I consulted several engineers about putting in a small pumping plant, on account of the flat grades which would otherwise be necessary, but I let it go at that.

The 8-inch sewer with a grade of one in 500, has been cleaned three times in a year, but generally it has been cleaned only twice a year. It is not really bad at any time, that is, no one has complained of it.

We do not ventilate through the houses. They seem to have objections to that in Malden.

The Chairman.—Do you have open manhole covers in Malden?

Mr. Wetherbee.—We have open covers at present, but we shall not have if the Board of Aldermen let me stay there long enough. I have closed a great many with oak plugs. Some of the oak plugs have been in there five years. I shall put on tight covers eventually. I have experimented a good deal with the ventilation, and I find that, in a great many of the low sections the current goes downward through the holes in the manhole. The only complaint of odor we have had was from a manhole at the head of a small sewer. A plug had been left in there and there had never been any connection made with the sewer, so it was perfectly tight. Some of the neighbors complained of an odor, but the manhole was as dry as a bone; there had never been any connection made with the sewer.

Mr. Wetherbee.—We have three inverted siphons at brook crossings and have never had any trouble with them. We have two manholes, one on each side of the brook. The one on the lower

side is sunk perhaps three and a half or four feet below the line of the sewer. That fills up with sand, and I presume in the year we get out two-thirds of the cubic contents of the sump. Of course through some of the low lines we have to scrape a little, but not very much. We have just about finished now.

Mr. A. C. Townsend.*—Mr. Chairman, I did not expect to be called upon this evening, and I did not prepare myself to make any remarks.

We have a very fair sewer system in Lynn. It was started along in the early 70's, and the original sewers were laid with practically no engineering. As some of the men who have cleaned them out have said, "They look as though they had been laid by a blind man with a broken-down level." So I don't think I had better make any comments about the grades of those sewers. Practically all the trouble we have with the care of sewers, or our maintenance work, is that connected with the old sewers. The new sewers which have been built within the last twelve or fifteen years give us practically no trouble, but the grades of those sewers are about one in 300 or 400. The worst thing that I ever got up against, as the boys say, was cleaning the sewers where there was a soap factory that lost a tank of soap into the sewer. We had a 36-inch brick sewer, with a very slight grade. It seems that there was some sediment of sand, etc., in the sewer. The soap factory, when the soap was boiling, lost the contents of this tank, and the whole tank full of soap got away into the sewer. It was cold weather, and a few days afterwards we had a complaint that the lateral sewer pipe was stopped up. I sent the man who had charge of the maintenance up there, and he looked it over, and he said, "I don't know what to say; it is as hard as a rock." That is all I could get out of him. We tried all kinds of hoes and scrapers, and we found the main sewer was so bad for 300 or 400 feet that we actually had to put a man in with a rubber suit on, on his hand and knees to chop into it. We finally pulled out one chunk, one piece of soap, that was longer than I am tall, and about as thick through as I am. I think that is the worst thing the Lynn sewer system ever had. Altogether we took out three or four tip cart loads of hard soap.

The water was cold in the sewer, so that just as soon as this hot stuff struck it, it stiffened up, and it completely filled up the sewer connection.

In our general maintenance and flushing of sewers we use mostly the hydrant hose in the manholes, and we find it is fairly satisfactory, pushing the sediment through the small pipes into the

* Superintendent of Sewers, Lynn, Mass.

main sewers and there taking it up by buckets. In very large sewers, six-foot sewers, we use boats. As I say, the sewers built in the last fifteen or twenty years have given us practically no trouble. We have given them a good inspection frequently, and it averages just about every three months that the inspector makes a tour of the city. If he finds something wrong on the old sewers we have considerable trouble. We have 30 or 35 sections that we flush at least every month, no matter whether winter or summer.

In regard to roots, we have had very little trouble. We had one or two cases where we thought there were roots, and ran our rods and hooks in and found that the roots were just started, and we caught onto those and pulled them out all at once.

I am sorry that I did not know that I was to be called upon, because if I had I would have made a little story which perhaps would have been of interest to you.

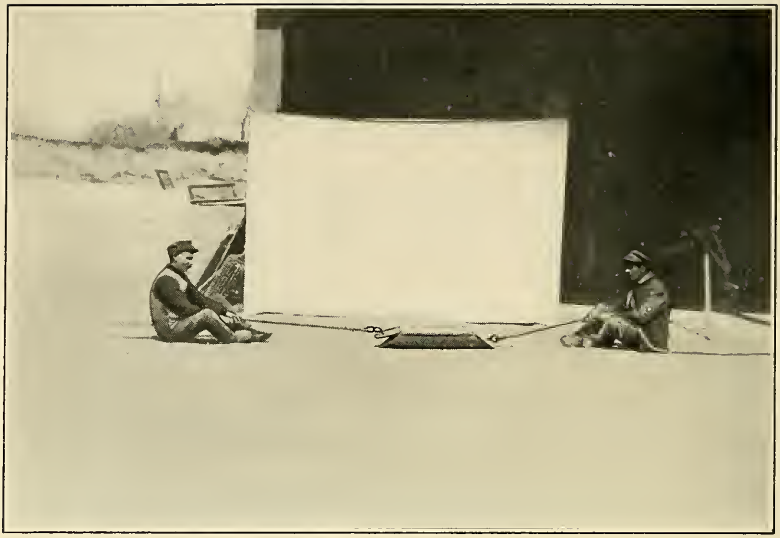
The Chairman.—Have you any idea, Mr. Townsend, how much money you spend on maintenance?

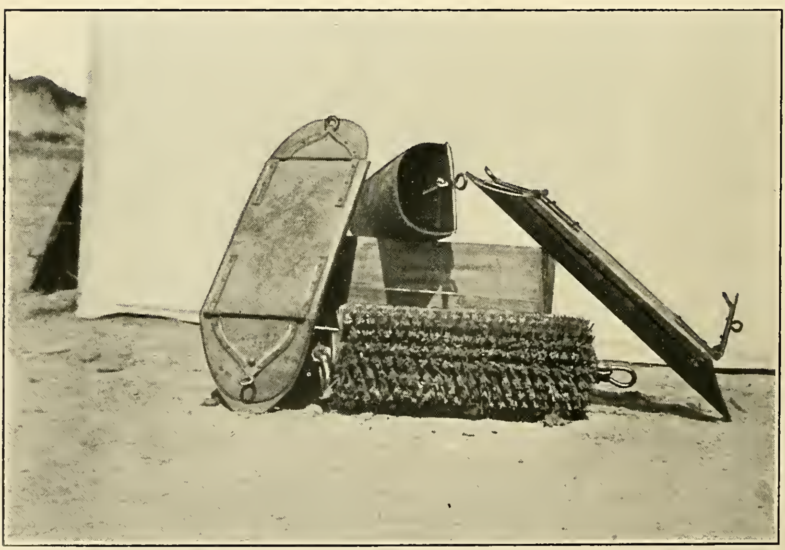
Mr. Townsend.—Well, I cannot give the figures on that, for this reason: Our catch basin cleaning and sewer cleaning is done under one head, and until recently we never had a satisfactory method of keeping books, so we could not tell exactly what our maintenance was. In the last three years we have started on cleaning out some main sewers that have not been touched for perhaps a dozen years, and that has increased the cost.

We have about 75 miles of sewers, and we have $10,000 appropriation every year for the care and maintenance of sewers, and with that money we have to clean out our catch basins and make our repairs to the sewers and our repairs to the catch basins, etc. We always have money enough to go around, so it is not very expensive, but at the end of this year I shall probably be able to give figures on the cost.

Mr. E. W. Branch.*—We have in our system about 40 miles of sewers, all built on the separate system, and at the start we had a pumping station, but the Commonwealth has taken our pumping station, so the money we spend for maintenance is for flushing and cleaning of sewers. The annual appropriation is $1500. The cleaning of the sewers is under the direction of the Board of Public Works, and I only know by observation about the details of the work. They flush about once in six weeks, from the flushing manholes at the summits. I think we have about 125 of these flushing manholes; we do not have automatic flushers, but turn on the water when we want to flush. We find that flushing every six weeks or

* Engineer Sewerage Commissioners, Quincy, Mass.





two months keeps the sewers in good condition. Most of the sewers have been scraped once in the last two or three years. There has been quite an accumulation of a sort of fungus growth, and that they take out with a rattan brush, which works very successfully, and the flushing, as I say, keeps the sewers very well cleaned. There are some places where the sand has got in through the ventilating manhole covers, and we were obliged to scrape the sand out. We have devised a scoop which I have not seen anywhere else, which worked very successfully.

In regard to grades, we get the best grade we can, and we started in on our 8-inch pipe with nothing flatter than a foot in 200; but I think we have one place where there are 700 feet of 8-inch pipe laid with a foot in 400, and we have had no trouble there. The maintenance men tell me that they see no difference in taking care of that, and that there is no greater accumulation of solid matter there. On the larger sewers we started in to get nothing less than one in a thousand, but in the last year we laid some 8000 feet of 20-inch pipe one in 1800. I suppose the cost of maintenance will be increased there, because more flushing will be necessary.

THE CHAIRMAN.—What has been your experience with the sewer having a grade of one in a thousand; has that been troublesome?

MR. BRANCH.—The most of the cleaning of these sewers has been on account of this growth that I spoke of; it seems to be something that accumulates.

THE CHAIRMAN.—Above the water line?

MR. BRANCH.—In the water. It clings to the sides of the sewer and in some places there remains only a narrow channel for the water in the center.

THE CHAIRMAN.—Can you tell us about the scoop?

MR. BRANCH.—The idea originated with me. I had something like a double-ended sugar scoop, with partition in the middle, made from sheet iron. A rope was attached to each end, and it was pulled through the sewer from manhole to manhole. If there was too much sand for it to be pulled the whole distance at once, it was pulled back to the manhole from which it started; the design being to get a load in both ends of the scoop.

In practice, however, we found that in pulling it back much of the sand was washed out by the water. To prevent this the foreman in charge of the work improved the design by having a cover fitted to the top of the scoop with a hinged cover on each end. These end covers are connected by a rod through the scoop so that when one cover is open the other is shut. The ropes by which the scoop

is pulled through the sewer are attached to these covers, so that whichever way the scoop is being pulled the rear cover is closed.

QUESTION.—I would like to ask how this operates in the different-sized sewers?

MR. BRANCH.—We have scoops for the different-sized sewers. We thought we might need them, and we had a set of different sizes made up—8-inch, 10-inch, 12-inch, 15-inch and 18-inch. I think we have just one place where roots have begun to grow into the sewers. It is in a street where there are willow trees on each side of the street, and we expected trouble there.

MR. FULLER.—I would like to ask, Mr. President, whether there is anything that keeps the scoop up from the bottom, or whether it draws along on the bottom?

MR. BRANCH.—It draws along on the bottom.

You were speaking about stoppages and cleaning devices. We found we had two or three stoppages right in the bend of the Y connections, and we devised something, which we have not had an opportunity to try as yet; we fit a spring, such as the plumbers use for bending lead pipe, to the end of our cleaning rod, with a chisel on that. We think that will go around the bend and clean off the obstruction. We have had about two or three of these stoppages right in the bend.

THE CHAIRMAN.—Where do you use this spring cleaning device?

MR. BRANCH.—In the house connections. All our connections are made in a direct line from the sewer.

THE CHAIRMAN—Are there any siphons in your city?

MR. BRANCH.—No, sir, we have no siphons.

MR. BARBOUR.—What is the length of the scoop?

MR. BRANCH.—The scoop is about three feet long.

MR. W. H. PATTERSON.*—We have some lines of 15-inch sewers that are laid at a grade of one foot in 1000. We also have one or two 18-inch sewers that are laid one foot in a thousand. I will say that our 18-inch mains laid at that grade are not costing us any trouble at all. We have one section of 8-inch pipe, about 500 feet in length, that is laid where the state bath house connects with our sewer. Some three years ago the bath house connected directly with the mains, and some three inches of sea sand had collected in this pipe, which I have been unable to clear out until this spring, but I think I shall be successful in doing it now. That pipe was laid at the same grade as the 15-inch pipe, and we have cross connections coming in from a 12-inch pipe, which causes practically a dam.

* Superintendent of Sewers, Revere, Mass.

That of course has made some trouble, and yet we have worked along with it. I have been obliged to flush it in the summer months as often as every two months, but I have never had any serious trouble with it. The outfall sewer runs to a receiving tank, which discharges only on the outgoing tide, and the quantity of sewage is so great that the tank has not sufficient capacity, and the sewage backs up into the sewers; consequently we are making a storage tank of our whole system. We have some 2000 or 3000 feet of that 18-inch pipe laid at that grade, and at every tide we find that we are backing up and filling up our system. Of course that has considerable to do with the matter of keeping it clean. But I think we will not have trouble with it. I am using a scoop that was made by Mr. Harold Vaughn, and apparently it is doing the work; I am just beginning to use it, and I am not thoroughly satisfied, but I hope we will be able to make it work satisfactorily.

We have some flat sections where small sewers are laid, as flat as one foot in 800, and that has not caused us any trouble.

The flushing of the system is entirely by fire hose. We work by sections. We get from 65 to 70 pounds pressure at the hydrant, and use 500 or 600 feet of hose. It of course reduces the pressure at the manhole quite a little, yet I think it is doing and has done good work.

Now, Mr. President, in relation to roots. We have had considerable experience with them this spring. We had some sections where there were roots growing. I had one section of 8-inch pipe that was laid a little better than 10 feet in 1000, and I have cut roots from that pipe this spring. It is wonderful to me how the sewage ever got through, but that section has been in operation all the time.

I first discovered there were roots there nearly three years ago, but I was unable to get the necessary tools to cut them out until this spring. We kept the system in operation, but it had gone about as long as I dared to trust it. Those roots are full of worms, dirt and all kinds of matter, and still the sewer was doing its work; it was not even backing up from one manhole to another. Of course I cannot understand how it was done, but it was done just the same.

I am now cleaning another section where we had a stoppage some two years ago from roots. I managed to cut the roots, and got it started, and it is working all right since, but we are taking out bunches of roots somewhat smaller than those found in the first section.

I agree, Mr. President, with the gentleman from Malden. I believe it is all in good construction. This pipe was laid some 12

years ago, and it was done by contract work; and the committee in charge of the work, so far as I have been able to learn, insisted that the engineers employ local men for inspection, and it would make almost anyone dizzy to look through the pipes. The pipes which have been laid within the last few years have not bothered us. As Mr. Wetherbee has said, when you get them as straight as a gun barrel, so you can see right through them, I don't think you will have any trouble with them. That is the way with those that we have laid in the last two or three years. When you get the joints so that the roots cannot get through, you do not have much trouble.

Mr. Fuller.—Were the roots solid?

Mr. Patterson.—They were in a solid bunch, and filled with sewer dirt. I have several bunches of roots that I cut when I first started out, and if I had known the discussion was coming up here I would have brought some up here to-night.

There is one peculiarity, Mr. President, that I would like to speak about. When I first discovered these roots running through the pipe I reached into the side of the pipe and gathered up a small bunch of roots in my hand and when I brought those roots out of the pipe, there were three spears of green grass growing on those roots. I called it to the attention of the men there and we wondered and always have wondered how they got there, but they were there just the same.

Mr. President, I don't know that I want to say much of anything more in relation to flushing, but there is one thing that perhaps I did not finish up.

When I found we were getting sea sand, we caused a change in the bath-house connections, and connected with a catch basin, which I think effectually stopped the sand coming into the sewer, but I have not got rid of the sand that I received previous to that time. I am in hopes to do it with the use of the scoop, but it is not very fast work. Of course it is continually working, pushing it in and pulling it out, and I think we get the scoop about two-thirds full easily. We get through, ordinarily, 200 feet of pipe, with four men, in a day.

A Member.—Mr. Chairman, I should like to inquire in the case of roots if it is fair to suppose the pipe was broken in a great many cases?

Mr. Patterson.—I don't think the pipe was broken at all; I think they all came through the joints. I undertook to look into one section, and, so far as I could see, I think in nearly every joint there were from one to half a dozen of the roots coming through.

Mr. A. A. Adams.*—It is an unexpected pleasure to be here. I can say that we have in Springfield a combined system of sewers made up of about 25 miles of masonry and 75 miles of pipe sewers. For flushing purposes we have direct connections with the water system at all terminal and some intermediate manholes. The flushing is done continuously, the entire system being flushed in from four to six weeks, which seems to be often enough. We have not had a great deal of trouble with gravel and sand in the sewers, and I know of but two instances of sewer stoppages on account of roots, one case being accounted for by lack of proper attention.

The Chairman.—What is your minimum grade?

Mr. Adams.—That is a matter I am not very familiar with as our engineer lays out the sewers. I think, however, that our minimum grade approximates one and six-tenths feet in one thousand feet.

Mr. Eddy.—Mr. Chairman, I want to say just a word about grades. You asked about 15-inch in sanitary work. I cannot tell you about that. But I find in this table we have in a combined system an 18-inch sewer laid at grade of .62 in a thousand feet, also a section .58 in a thousand feet, which comes pretty near one in two thousand, and that is where we have some trouble with deposit as we have to scrape that section out. Where we do not have trouble the minimum slope is 1.7 in a thousand. I have no doubt, from observation, that this sewer, laid at .58 in a thousand feet, would give no trouble in a separate system. There has been a question raised by Mr. Branch concerning the growth inside of the sewer. If I recollect correctly, the town of Westboro had a great deal of trouble with growths inside of the sewer. I don't remember the name of the fungus, but I think it was caused by a large amount of ground water getting into the sewer. The pipe was relaid, and my impression is that there was no more trouble after that. You will find a description of that on page 674 of the State Board of Health report for the year 1898.

Mr. E. C. Frost.†—Mr. President and gentlemen: Our system was designed and built in 1888, a separate system, containing about 15 miles at the present time, at an expense of about $225,000, including pumping station, force mains, filter beds and everything in connection therewith.

We flush our sewers with the hose and hydrant about four times a year.

There is one thing which we formerly did which we have

* Superintendent of Streets and Sewers, Springfield, Mass.

† Superintendent of Sewers, Framingham, Mass.

neglected for the last three or four years, which I propose to do this year, that is, near the dead ends to put in quite a liberal shovelful of potash. The gentleman on my right said that he had considerable trouble with small pipes from a greasy substance clinging to the sides and leaving a clean channel in the center. I think if he would try the potash he would clean the brick so the grease will not adhere to it so quickly. I know it works well in our place and it costs very little.

In flushing I use an open inch and a quarter nozzle. I have been able to clean out stones the size of a hen's egg with my inch and a quarter nozzle. We have a hydrant pressure of 94 pounds, and with a little calculation you can clean the sewers out pretty clean.

We have laid within the last three years, with the assistance of the Commonwealth, about 1½ miles of 18-inch iron sewer pipe with lead joints. This sewer runs under the Sudbury aqueduct in an inverted siphon, which has been in operation about nine months and has given us very little trouble. This siphon is flushed by closing a gate at each side of a manhole situated at the upper end of said siphon and filling said manhole with water; then, by raising the gate, the sludge accumulation is removed by the water pressure. This may be repeated until the siphon is clean.

There has been considerable said about roots growing into sewers. I think the trouble all comes in construction. There is no question about that. I have gotten roots three or four feet long out of sewers. Maple roots will grow in through a brick wall; they will go through where some man who didn't know his business, and was not watched, has left a little bit of the jute sticking out through the joint. If sand gets between the pipe and the cement in construction, the roots will grow around between the sand and the pipe and get into the sewer.

There is very little satisfaction cleaning roots out, because they grow right up again. When you find roots in the sewer, the best way to do is to dig it up and lay it over.

In regard to our filter beds, we have about 21 acres under cultivation, and we are pumping about 900,000 gallons of sewage, and we have had no trouble taking care of it, except I came pretty near being frozen up this winter, with the large amount of snow we had. I think some of the Worcester people can sympathize with me in that respect. Where I have a bed that takes 900,000 gallons for three days, in ordinary times I could fill that bed in three hours with the same flow, so you see our beds came pretty near being tied up. I have thought sometimes that in inland towns in Maine (in a climate colder than ours) this system

been crowned with such encouraging success. Nevertheless, a fair comparison of the inherent differences in the two problems should receive due consideration. The first has been hinted at above. Ashes, rubbish, garbage and sometimes even street sweepings are gathered up together and are in no way separated during their treatment at the "destructor." In America it has been accepted without argument, until it is almost considered axiomatic, that garbage must be kept and collected absolutely apart from every other class of refuse, except dry combustible waste, and, of course, in the reduction process even this must be eliminated. There is, moreover, a very prevalent sentiment against the draining of garbage, although it is hard to recognize any good reason why the liquid from garbage would be any more offensive or dangerous if put into a sewer than the matter already there. But the fact remains that the successful American furnaces have to receive and evaporate the full amount of water contained in garbage as it is collected from the houses. The average amount of moisture in garbage proper is 70 per cent., while that in the entire waste production of a city rarely exceeds 25 per cent. It is not strange, therefore, that the bare cost of destruction per ton is largely in favor of the English plant.

Further, it is obvious that the most economical work can be done where the largest amount of garbage is to be destroyed, and the largest, most modern and best equipped plant can be erected. Our American custom of placing such public utilities in the hands, and too often at the mercy, of a private contractor, has had, to a lamentable extent, the result of throttling sanitary progress in this direction. With the exception of recent noteworthy experiments made by the Street Cleaning Department of New York, some similar work at Boston, and the unfortunate experience of Milwaukee, with crude crematory furnaces, none of our large cities have erected municipal plants. The individual who has a short, or even a long, term contract, being in the business for what there is in it, will make no improvements in the process which do not directly increase his profits, and will not erect a plant of the permanence desirable in such works. There can be no question that our political system is at fault here. It would be as reasonable to let out the maintenance of a sewer system and operation of a sewage disposal plant to a private contractor. The result has been a forcing upon the smaller and less opulent towns and cities the brunt of the expense for most of the municipal experimenting and investigation that has been carried on with consequently, and quite naturally, a slower progress toward the goal desired.

The English destructor furnaces are built on the cellular plan;

the refuse being received and thrown first upon a drying hearth is afterwards raked or shoveled on to the grate proper, where it is burned. The residuum is clinker with a slight intermixture of fine ash. The steam boiler, generally of the water-tube type, is an integral part of nearly every modern English destructor plant, the power in most cases being used for lighting the plant, working conveyors and other machinery, and in at least one instance the condensation water has been made to supply heat for a public library and bath house.

A type of the most successful American furnace is an elongated shell of steel lined with fire brick, provided with a horizontal fire-brick grate, upon which garbage is directly dumped as received at the plant. Fires at one end throw flames above and below this grate the full length of the destruction chamber, and the escape of obnoxious vapors passing off from the garbage during the early stages of cremation is prevented by the "stench cremator," located at the base of the stack, through which all gases of combustion must pass, and where by the high temperature they are rendered innocuous. Small pieces of burning rubbish and impalpable particles carried off by the draft impinge on fire tile which are kept at a white heat and falling back are destroyed in the fire of the stench consumer. Owing to the method of operating American crematories, and the fact that the combustion is not continuous during the full 24-hour day, there is considerable liability of producing offensive fumes when fresh garbage is thrown into the heated furnace at the beginning of the day's work. It is at this time that the stench cremator justifies its existence, which has been loudly criticised by advocates of the English system. Most American furnaces work under natural draft, but when the first stage of combustion has been passed and the garbage is well dried out and burning freely, the temperature is sufficiently high to obviate further need of operating the stench cremator.

It is usual, abroad, to supply destructor plants with artificial draft. While Sturtevant fans are widely used, the steam blast seems to be in general favor. It would appear, however, from the high chimneys with which most of the plants are equipped that the English engineer has not yet had sufficient experience with artificial draft to be sure of his results; or else that the destructor dust (which contains about 15 per cent. of organic matter) and for the interception of which elaborate precautions have been taken, is still a frequent source of nuisance.

This is, indeed, the bugbear of the English plant, just as the production of gaseous fumes is of the American. One of the most

of purification was practicable, but after passing through last winter, I have changed my mind.

Mr. Bowers.—I would like to say, Mr. President, that I have had considerable trouble with roots in sewers and I want to say that I agree with what the last man said. The time spent trying to cut off the roots is all wasted and I think when you find the roots you had better take up the sewer and relay it.

Mr. Frost.—Just one more word to tell you what roots can do; the water for our boilers comes from a pond through an 18-inch Akron pipe, with Portland cement joints. There is one place near the pipe where there were a few willow shrubs growing. A year ago this summer we could get no water for the boilers through this pipe, and I found the roots from these willow trees had grown into the 18-inch pipe. One was 20 feet long, one 24 feet long and the other 30 feet long, and they filled the pipe so full that a muskrat could not get through. One had tried it and his carcass was found among the roots. I had to break the pipe at the point where the root grew through, in order to remove what had grown inside the pipe.

FABLE AND FACT AS FACTORS OF PROGRESS.

Address by J. L. Van Ornum, President of the Engineers' Club of St. Louis.

[Read before the Club, December 16, 1903.*]

Aurora, radiant goddess of the morning, was represented by the civilization of the ancient world as standing in a chariot drawn by winged steeds, one hand grasping the reins and the other holding a torch, while a brilliant star sparkled in her forhead; thus she dissipated the gray twilight of the morning by her splendor, awakening the dark sphere to a glorious life as her swift steeds flew across the world. What imagery could better typify the import and achievements of modern transportation?

Consider what our civilization would be without the steamship and the locomotive. Although they have been in operation less than a century, the civilized world has been completely transformed by their agency and by the later perfection of the electric car. The motor-car and carriage are even now exerting their influence upon our civilization, tending powerfully to remove the great contrasts between urban and rural life to the advantage of both; while the final conquest of nature by the subjugation of the air bids fair to complete this Eoan simile.

Contrast the facility of travel now with its difficulties when not served by these agencies; a journey to the Pacific meant months of hardship where now only an equal number of days is needed; or compare the fatiguing journey of Washington to his inauguration, consuming days where an equal number of hours now covers the distance in comfort. Ocean travel has been transformed since the "Savannah" in her passage from Georgia to Liverpool, in the year 1819, first used steam.

The history of the great Santa Fe Trail illustrates forcibly many such contrasts. In the early part of the nineteenth century this great overland route of nearly a thousand miles consumed a season for the journey from the Missouri River to Sante Fe and return. It was not until 1829 that the introduction of wagons was effected, rendering transportation possible though the difficulties and dangers were still great. One party, having lost its animals in a stampede and forced by hostile Indians to abandon its supplies and to walk to the settlements, thus describes its experiences:

* Manuscript received September 29, 1904.—Secretary, Ass'n of Eng. Socs.

"After eight days' travel, despite our most rigid economy, an inventory showed that there was less than one hundred pounds of flour left. Day after day the hunters repeated the same old story. 'No game'! For two weeks the allowance of flour to each individual was but a spoonful stirred in water and taken three times a day. . . . . Now, in addition to the pangs of hunger, a scarcity of water confronted us, and one day we were compelled to resort to a buffalo wallow and suck the moist clay where the huge animals had been stamping in the mud. . . . . Having journeyed (for weeks) until we supposed we were within a few miles of the settlements some of the number, scarcely able to travel, thought the best course to pursue would be to divide the company, one portion to pass on, the weaker ones to proceed by easier stages; and when the advance arrived at the settlements they were to send back relief to those plodding on wearily behind them. Soon a few who were stronger than the others reached Independence, Missouri, and immediately sent a party with horses to bring in their comrades; so at last all got safely to their homes."

During the next twenty years the time of a trip was gradually reduced to somewhat less than three months, and the cost of hauling freight was reduced to $200 per ton; while the tariff now on merchandise by train is about one-sixth that rate. In the score of years preceding the approach of the Sante Fe Railroad, Concord coaches were in use, charging $250 for each passenger, and gradually reducing the time to two weeks. The trip was continuous, night and day, "With no chance to stretch your limbs, save for a few minutes at stations while you ate and changed animals." Now this same route is traversed in comfort in one and one-half days, and at a cost of less than one-eighth of the charge just given.

The saving in time and comfort of travel is not the only significant result. The safe, speedy and distant transportation of commodities is of equal importance. Grains from the higher latitudes, meats from the piedmont ranges, fish from the seas and fruits from the tropics are collected with equal facility in our centers of population. We have only to compare the conditions of our own republic with those of less progressive countries to realize the full import of modern transportation. Even now famine decimates the population of various provinces of India when there is a local failure in agricultural products; starvation would be equally our inheritance if we were without modern transportation facilities.

Of course other agencies have also profoundly affected mankind in its progress; but I know of no single influence which can be so significantly pointed out as typifying the beneficent achievement

of the present day as that of transportation, which is the engineering interest which unites the most completely all our various branches—civil, mechanical, electrical, mining, metallurgical and marine. Thus did Aurora in her chariot well typify transportation; the winged steeds signifying its speed, the guiding reins indicating its perfect control through the power of steam and electricity, and the lighted torch emblematical of the enlightenment of nations that has resulted.

Homer tells us that Neptune rose from the depths of the ocean and traversed the entire horizon in three steps. This dream of marine mythology was surpassed by the achievement of the ocean cable laid by Cyrus Field less than fifty years ago; and the extravagant fancy of the king of dramatists uttered three centuries ago "I'll put a girdle round about the earth in forty minutes" has been more than realized within the year, when a message was sent around the world in less than one-fourth that time.

Artemis, the young and swift huntress, with her bow and quiver on her shoulders, pursuing her course as rapid as the winds, may typify the modern telegraph which Morse made practicable sixty years ago. And Mercury, the swift messenger of the immortals, "The fleet, inventive idea sent from heaven to earth," is emblematical of the telephone which has been a real necessity in our busy life for a score of years; even the remarkable fidelity in reproducing the tones and modulations of an individual voice at great distances is suggested by the attribute of inventive cunning given to Mercury by the ancients.

Among mythological deities the winged Pegasus was supposed to especially preside over fountains; and where his hoof struck the earth springs would gush forth. The god-like Perseus, son of the all-powerful Jupiter and the arid earth, when suffering of thirst secures water by plucking a mushroom from the earth and so causing a spring to flow from the place it occupied. The great, and sometimes surpassing, importance of water as a factor in the productivity of some of the Mediterranean countries is indicated by the fact that the supreme Jove himself is represented as striking the earth in a particularly arid region and thus causing the essential fluid to flow in abundance.

The modern miracle brings water from the earth by no divine dispensation, but so constantly and with such compelling power that waste and arid places are transformed to choicest lands. One section of our country (which, thirty years ago, was a sandy waste with only occasional flocks and herds securing but a meager return to the few inhabitants) has been transformed by this agency alone into a region whose productivity is ten times the average for agricultural

lands; whose income per inhabitant is a hundred dollars per year; and whose transformation is more wonderful than that told in the legendary myths themselves because it is so general. This instance is but one of many where the vivifying flow of the developed streams has awakened these arid, forgotten lands from their doom of solitude and silence to their rightful sphere of richest fruitfulness. Even yet these pioneer communities are but the outposts of the conquering power which has but just begun the great, decisive campaign against nature in her most forbidding mood, whose strategy rests in the quiet but compelling control of the irrigation engineer.

You will remember that Prometheus, in endeavoring to kindle his torch at the chariot of Phœbus, incurred the opposition and wrath of Jupiter; but he finally succeeded in evading the angry deity by concealing the ethereal fire in the stem of a reed. And so approaching his creations on the earth with the divine flame they responded to the influence by beneficent activities. What imagery could more aptly typify the silent but constraining power of electricity in our day than does this legend of that inventive genius whom mythology credits with teaching men the useful arts?

The mining engineer is, perhaps, foreshadowed in Theseus, who dared to descend to the depths of Orcus to bring back to the light Proserpina, the goddess in whose hands lies the fate of men (as it so often seems to lie, especially with the precious metals). Whitney's cotton gin, the Hoe printing press and other mechanical wonders are certainly not less marvelous than were the stones which Deucalion and Pyrrha threw behind them, so changing them into human beings. The beautiful but suffering Niobe, mercifully turned into stone by the pitying gods, may be symbolical of cement. The Aloeidae, who strove to place Mount Ossa upon Olympos and Pelion upon Ossa, easily suggest the designer of high steel buildings of to-day. Phaëthon, rashly aspiring to drive the chariot of the sun for a day, was for his presumption struck by a thunderbolt and hurled into the river Eridanos; to-day our river of the Falls yields electric energy surpassing a thousand thunderbolts in power. As the prototype of all the varied interests of the engineer, what better character exists in all mythology than the stern and daring Minerva, goddess of the liberal arts, civilizer and benefactress of mankind, whose very symbols* were considered the badge of strength and wisdom.

Such were some of the fancies and conceptions of the human

* The Gorgon's head on Athena's breastplate.

mind in the early dawn of civilization, when desires and needs were perhaps as great as now, but when attainment cheered only those divinities whose achievements were the Utopian dreams of mortals. And such again are some of the facts of the modern world, actualities whose reality are so interwoven with our every-day life that they seem no longer wonderful. There was the prototype, here is the product; there the dream and prophecy, here a fulfillment even now surpassing the imagination of the ancients, while the future abounds in greater possibilities and promise.

The poetic minds of the ancient civilization conceived such fantasies of surpassing achievements, weaving them into legendary tales in which the characters possessed powers and attributes most extravagant. In this atmosphere of legendary prowess successive generations of the cultured classes dreamed their heroic dreams and achieved somewhat, while the masses of men toiled in ignorance and slavery, making "bricks without straw," irrigating fields with the foot, gleaning grain with the sickle, mining by the excessively tedious and dangerous "fire-setting" system; navigating, but as galley-slaves; warring, but as conscripts; engaging in overland commerce, but by wagon-train or caravan; constructing aqueducts to supply the masters, not for the general salubrity; erecting monuments, temples and other works, for the delectation of the few. The achievements of the ancient world were such that the mass of men could have in them no personal interest or part. While the few aspired and flourished, exhibiting in themselves the ultimate in their civilization, such favored ones inevitably were doomed in the might of the virile upheaval of the barbarian hordes. When that classic culture fell, none could perpetuate its splendor; for the refinement of the ancient world had been segregated and secluded, and its vigor had become so attenuated even among its devotees, that its power to vitalize mankind was gone.

Many centuries passed. A new principle was struggling for expression during the lethargy of the dark ages. Among all ranks of men there were those who variously tried to impress the supreme import of the brotherhood of man. Some labored feebly, others vociferously, and others again strove by force of arms to impress the truths of human interdependence. But their resources were so circumscribed, the horizon of endeavor and influence was so narrow that progress was spasmodic and most uncertain until abstract principles were vivified and given opportunity by the unfolding energies of the modern world.

What real significance had "humanity" when thousands starved for want of that which was plentiful not far away? What virtue

had "fraternity" in the crowded, reeking cities until the sanitarian banished the plague and insured their salubrity? To the humanist "brotherhood" became significant when the printing press, railway, steamship, telegraph and telephone brought all the world within his interest; and "altruism" could claim the world for its dominion when the engineer had brought the world within its reach.

Classic story charms the hearer, offering its Utopian dreams; humanistic disquisition inspires the thinker, contemplating human interests; and science, pure and applied, absorbs the energies of him who pursues its unfailing principles. The first idealizes; the second moralizes; the third executes; and who would say that the last is of less import than the rest?

Unquestionably the classicist by no means confines his interests to idealization, nor the humanist to dissertation, nor the engineer to accomplishment; it is merely attempted here to indicate the characteristic spirit animating each. Occasionally very intolerant views have been expressed by men who could see little of culture, mentality, wisdom or worth in those whose life and interests were diverse from their own. For example, recall Lowell's definition of a university as "A place where nothing useful is taught." Even recently one of our college presidents said "Technical schools have their place, but they have no part in a university." The former statement may be due to that ancient attitude of the feudal mind whose capacity was of one dimension only—that of length; and the latter partakes of the pseudo-practical, thinking to attain to volume by assuming the added attribute of breadth. The third dimension—depth—has been brought by him who directs the forces and resources of nature to the use and convenience of man; but its coming was not helped by such misconceptions. Such intolerant views, rapidly getting rarer, are survivals of the aristocratic spirit in education, which has practically disappeared before the democratic tolerance of the present, infusing a new vitality into education and transforming it from the feudal type to one of broad beneficence. Traditions had and have their part, idealizing toward the intellectual and spiritual; disquisition finds its most abundant reward in the culture of society and the exaltation of citizenship; and "The priest of material progress" has intensified living and enlarged the scope of life until it has no horizon but the limits of the universe.

Action, thought and life itself have become intense, until a decade of the present accomplishes more than a thousand years of the ancient world. Activity is an unfailing index of life; and if the index points high should not we read the record as indicating a more profound and abounding life? The engineer is often charged

with much responsibility in connection with the strenuous vitality of the present; and truly so. But when his spirit of energy is charged with increasing the burdens of the world, I must protest. These intensities of life are functions that are involved in life itself,—the duty placed by Providence upon all who live to swell the sum of life's veritable accomplishment. The engineer, then, through the avenues of his endeavor, has assumed life's duties with the constant aim of enabling the world to fulfill its destiny with the least expenditure of human energies. The purpose of his activities is not to add increasing burdens to the tense life of modern civilization; but, accepting willingly life's law of progress, his purpose is to conserve, and so to promote the powers of mankind.

The engineering profession is never charged with lack of depth. Rather does communion with nature's laws and resources give cause to fear that such profound pursuits may tend in him to overshadow that breadth of human interest and that limitless mental vision which all unite to mark the man of equipoise. The three types of mentality which I have indicated are in fact co-ordinate attributes of him who would fulfill his destiny the most completely. And so, consecrating to the service of mankind the apprehension of life's verities, the power to execute and the perception of the ideal, there shall be realized the fulfillment of the prophetic Minervan legend; the union of power and wisdom beneath the ægis of the world's accumulative attainment.

THE DISPOSAL OF MUNICIPAL REFUSE.

By F. K. Rhines, Member Toledo Society of Engineers.

[Read before the Society, July 16, 1904.*]

When the human race became sufficiently advanced to abandon its former nomadic existence, congregate in considerable numbers and erect permanent habitations, there was of necessity given it the problem of disposing of the rejected by-products of existence. The need for removing excreta and other deleterious liquid and semi-solid matter must have demanded early attention, although the development of the sewer system to a point of real efficacy has been the work of the modern engineer, and the final disposal of sewage is a subject to which much study can still be devoted with profit. But the removal and destruction of what may be termed "surface wastes" is distinctly a feat of the nineteenth and twentieth centuries. The scourges of cholera and "black death," which ravaged England and all Europe, were, even at the time, recognized, somewhat dimly perhaps, as related to unsanitary conditions; and great centers of population at a much earlier period took sporadic and ineffectual measures to get rid of the most offensive elements. We do, indeed, find mention of such in the time of Moses, and the enforcement of certain sanitary regulations was common to others of the more advanced races, but it is hardly likely that the ancients allowed themselves to be seriously troubled by what must have seemed an insignificant matter in comparison with the all-important questions of arms and conquest; and with the notable exception of the incineration of human bodies practiced by the Greeks, and to some extent by the Romans, such efforts were confined to dumping or tipping upon land or water, which, in the light of modern experience and investigation, cannot be considered as final disposal.

And yet to within the present decade, the greatest city of our country has depended upon this makeshift. It is scarcely three years since New York stopped barging her refuse out to sea, and abandoned, forever, let us hope, a practice which was a constant source of dissatisfaction to all concerned. And who is not concerned in such a matter as this? It is a question which touches the well-being of every citizen, and, as such, certainly merits the most serious attention.

Despite the fact that some very eminent hygienists contend that garbage is only detrimental to health in so far as the noxious odors

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exuded tend to deplete the human system, it is pretty well established that putrefying animal and vegetable substances are not only a frequent vehicle of disease, but that decaying organic matter affords a favorable breeding ground for zymotic disease germs.

An example of the most flagrant violations of sanitary precautions in this regard, and of the inevitable penalty, is to be found in temporary army camps. It is said that in the Civil War more soldiers died of dysentery and camp fever than were lost in battle. Those who are familiar with the conditions that prevailed at Chickamauga Park, during our recent war with Spain, will not for a moment question the cause of the shocking amount of illness among our troops—and this in one of the most healthful mountain regions of the entire South.

Was there ever an army thrown into the field, where proper sanitary measures could not be, or were not, taken, that did not have this subtle enemy to fight?

It has been said that epidemics are Nature's greatest health officers, and if this be so, interest ought to be widely stimulated by the recent experience of Butler, Ithaca and others. Just as Nature is unrelenting in her punishment of unsanitary modes of life, she is gracious in the reward of every effort toward better conditions. The cleaning up of Havana by the American military cut the previous normal death rate squarely in two, and it is hoped that as much can be done at Panama.

To cite just one instance a little nearer home: The city of Memphis, Tenn., has so successfully controlled her yellow fever by the adoption of a sanitary method of disposal of her municipal waste that the city has not been quarantined since the construction of her plants. From 1898 to 1904 her death rate has dropped from 22 to 15 per thousand.

Primarily this question is a sanitary one, but the tendency of engineering practice is to ally itself more and more closely to the great sanitary problems of the day. Sewer design and sewage disposal are conceded to be wholly the engineer's problem, and although garbage disposal in most of our American cities is under the direct charge of the Health Officer or the Board of Health, each day sees the question more frequently referred to the sanitary engineer for advice and recommendation, which the writer believes to be encouraging as conducive to an earlier and more satisfactory solution. But it must not be forgotten at any point that the prime object is always perfect sanitation, and that the process which sacrifices this, however ingenious and otherwise efficient, cannot be accepted as the ultimate solution of the problem.

The average composition of the refuse of New York, London, Boston and Berlin, as given by Morse, is as follows:

	New York.	London.	Boston.	Berlin.
Ashes	80.47 per cent.	81.55 per cent.	75.88 per cent.	52.97 per cent.
Garbage	12.20 "	14.20 "	20.19 "	32.54 "
Refuse	7.33 "	4.25 "	3.93 "	14.49 "

in which a wide variation is apparent.

Mr. Parsons gives the total refuse production per capita per week day as follows:

New York	3.9 per cent.
London	1.6 "
Berlin	.9 "

The amount given for New York, he estimates to be composed of: Garbage, .4 pounds; ashes, 2.5 pounds; rubbish, .3 pounds; street sweepings, .7 pounds; total, 3.9 pounds.

For purposes of more intelligent consideration, the general refuse production may be conveniently classified as follows:

I. Ashes (factory and domestic).
II. Street sweepings.
III. Rubbish.
IV. Garbage.

Then there are various special classes to be dealt with in different localities.

Prominent among these are:

V. Dead animals.
VI. Night-soil, or human excreta.
VII. Hospital refuse.
VIII. Trade refuse.

Disconsidering in this paper the question of primary collections, which, with all its importance and magnitude, may be easily mastered by careful study, it will be attempted to show the difficulties in the way of disposing of each class of refuse and a few of the reasons some methods of disposal succeed, while others fail to accomplish the ultimate elimination of the rejected matter so far as that is physically possible.

I. *Ashes.*—Being practically free from organic matter, ashes, if unmixed with other refuse, are in no way offensive, except for the dust given off when handled, and the question of what disposition to make of this class becomes merely one of expediency and economy. The common method uses them in redeeming waste lands. The points which make this economical, or the reverse, are,

the (a) distance necessary to haul the material, and (b) the value of the land thus reclaimed.

The question of expediency can rarely be given serious consideration, since, under existing circumstances, it is generally impossible to do anything but dump them, though a small portion, consisting of sharp steam cinder, is frequently worked into concrete, and some ashes find their way into mortar and road pavements. A number of our seacoast towns make excellent use of their ashes in reclaiming alluvial lands, which sometimes develop immense values. The extension of Riker's Island by the New York Street Cleaning Department, where some 70 acres of fill-land have been made, is valued at $10,000 per acre, but needless to say this is an exceptional return.

II. *Street Sweepings.*—In many instances, where these can be kept free from dry rubbish, these are profitably utilized as filler, but are not well adapted in all cases on account of their fibrous nature, due largely to the manure which they necessarily contain. Organic matter in street sweepings takes in the wide variance from 4 per cent. to 60 per cent., according to the nature of the pavement and other changing conditions. In addition to this volatile matter, tuberculosis germs are common, and the bacilli of diphtheria and typhoid are not infrequently found.

In short (though its manurial value in special cases has been demonstrated), the proper method of disposal for this class of refuse is not generally recognized, but its composition as well as the best practice seem to point to treatment by fire.

III. *Dry Rubbish* is admitted to be of value. In New York 35 per cent. is readily marketed, bringing to the city over $100,000 per annum. Say, 5 per cent. is incombustible and worthless. There is yet a balance of 60 per cent. of dry, combustible refuse, with a positive, albeit indefinite, calorific value. The solution here is obvious. This class of refuse should be made, in one way or another, to assist in the destruction of the offensive and less combustible matter, and the writer believes that with proper apparatus, even the percentage of marketable material can be better utilized for producing heat, and at the same time doing away with the unsanitary sorting process necessary to separate what is sold, resulting in a saving of both health and steam power. In London, let it be remarked, this degrading work of "picking" the refuse is performed largely by women.

IV. *Garbage* presents the chief difficulties to be met in the consideration of this entire subject. When it is remembered that this includes all manner of refuse from the kitchen, market, hotel,

commission house, fish stall and slaughter house,—in fact every sort of animal and vegetable matter, with, commonly, a considerable proportion of such inert matter as tin cans and broken crockery, and, frequently, small dead animals, it is seen at a glance how many factors lead to the complication of the disposal problem in this application. The system which will successfully dispose of one constituent must often utterly reject the others, while the process to have our ultimate and unqualified commendation, must care for every portion of this heterogeneous production with equal efficacy and without undue expense.

Solid garbage is about 20 per cent. putrescible organic matter, frequently highly infected, and its prompt collection and thorough destruction are imperatively demanded.

Among the methods for disposal now in common vogue may be mentioned:

1. *Dumping,* which is effected in three general ways:
   - A. Upon Land, { (a) as filler. (b) as fertilizer.
   - B. In Streams.
   - C. At Sea.
2. *Feeding to Swine.*
3. *Utilizing by Reduction.*
4. *Cremation.*

1. *Dumping.*—There is little argument that can be advanced in favor of this method, unless it be its antiquity. It is of interest here to note that in the English city of Portsmouth, which is still disposing of its refuse at a dump, or "tip," as it is called in that country, the Mayor was arrested in the year of 1694, and fined 6s. 8d. for tipping refuse in a public street; but this should by no means be taken as typical of English progress in this direction, as our friends across the water have given us much food for thought, as will later be shown.

(A) *Dumping Upon Land.*—Naturally, the first object in dumping garbage is to dispose of it. Apart from this must be considered the resulting advantages and objections of the method. (a) As a filler for lands upon which buildings are to be subsequently erected, garbage has shown itself to be utterly unfit. In experiments made at Brussels, garbage having lain on the dump for over nine years was found to contain more than 30 per cent. of organic matter, and a similar investigation at Boston developed the fact that after lying for ten years decomposition was still in progress. Unsanitary building sites became a sufficiently serious cause of danger

in London to occasion legislation prohibiting the erection of any building upon ground which had previously been used as a tip.

The most serious hygienic objection to this unsanitary practice is the danger of infection of the scavengers and "pickers" who make a practice of going over the material as it lies on the dump, pulling it apart and forking it over, searching for whatever may be of value. These persons are nearly always personally unclean, in feeble health and, living in crowded districts amid unsanitary surroundings, are the very class most likely to contract disease and carry it to others. If for the time the dump nuisance must in some cases be tolerated, this offensive and dangerous practice should at least be abated.

(b) As a fertilizer, more can favorably be said. For enriching certain kinds of sterile and impoverished sandy soils, garbage has been used with good effect, notably in some parts of Europe, where the fertility has been largely increased; but in this country at least, the cans, crockery and other rubbish commonly found in the garbage are very troublesome, and it is also difficult to find lands upon which to utilize the production of large cities.

(B) *Dumping in Streams*.—The decomposition of organic matter in water is very slow, and garbage dumped into rivers and small streams is usually carried down to pollute the water supply of other cities or towns, or to be cast up on the banks to become a prolific source of nuisance. It will be seen that this is not final disposal at all, but simply a shifting of responsibility in which no community has the moral right to indulge. The system is altogether false in principle, and cannot be too earnestly denounced.

(C) *Dumping at Sea* is subject to many of the same criticisms applied to the practice in interior regions. There is, it is true, the possibility of taking the material so far from shore that a comparatively small part of it will ever find its way back; but at New York, even when the garbage scows were taken as far as 50 miles out to sea, enough of the refuse was floated back to cause serious annoyance at the Long Island beach resorts, and the practice has finally been discontinued. A similar experience was had at Marseilles, and many others could be cited.

The city of Havana, after having been started in the right direction by the establishment of a crematory plant, is still sending a couple of hundred tons to sea daily, but it is not likely that this will be long continued.

2. *Feeding to Swine*.—It would appear at first glance that this is hardly an engineering problem, but the engineer is nothing if not an economist, and as this means of disposal still finds favor in

many of our American towns which cannot be called unprogressive, it is worth our looking into.

If it is not necessary to haul the garbage an unreasonable distance and local circumstances make it possible to secure an approximately uniform production of a proper quality of pure garbage, the financial economy cannot be questioned; but the expense of delivery is radically increased by the necessity of more frequent collection, and here again an objectionable feature is found in the foreign matter contained. Keepers of large hotels, who are frequently able to sell their garbage for this purpose, are justified in the special effort required to keep this material separate from the table offal, but it has been found extremely difficult, indeed well nigh impossible, to enforce such a separation generally throughout a city, and this objection becomes, therefore, so insurmountable as to preclude the possibility of adapting this method generally to the entire garbage production. The disease germs which are carried by the garbage become, moreover, a frequent source of menace.

3. *Reduction.*—An average analysis of city garbage is as follows:

Water	70	per cent.
Animal and vegetable matter	20	"
Rubbish, cans, rags, etc.	7	"
Grease	3	"

The reduction process consists, briefly, in extracting the grease from the balance of the material. As this is the smallest percentage, as shown above, the process is necessarily a laborious one.

In the first place, if not for the successful, at least, for the economical, operation of the process, the exclusion of all rubbish is absolutely necessary. The "pure swill" is cooked, usually by steam, in huge "digesters," which are steel tanks holding some 6 tons each. By the introduction of naphtha and benzine the grease is separated and removed, and later the residue is subjected to immense pressure to free it from water. What then remains, commonly known as "tankage," is of value as fertilizer base, but its marketing is such an uncertain element that it frequently becomes necessary to throw it away or burn it in order to dispose of it at all. Fair prices for the by-products are $60 per ton for the grease, and $6 per ton for the tankage, which superficially look rather inviting. But, as a matter of fact, no reduction process has yet demonstrated its ability to pay its own expenses, much less a dividend on the investment. The reduction system is now in use in some 25 American cities, and has been tried and abandoned in nearly as many more.

A few of the reasons why it has failed so frequently, and why its use is so slowly adopted are found in (a) the heavy cost of installation, (b) the cost of operation, (c) complexity of machinery required, (d) fluctuation of prices obtainable for the by-products, (e) difficulty of operating the plant during epidemics, (f) impossibility of locating the works in or near centers of population, on account of offensive operation, and consequent heavy expenses for transporting garbage; and (g) further, in the commendable hesitancy of municipal authorities to embark their civic charges upon such speculative enterprises.

It should be remembered that, even when comparatively successful, this process disposes of less than 15 per cent. of the total municipal waste production. At Barren Island, the New York City plant, where are located probably the most extensive reduction works in commission, the amount cared for is given by one authority as 8.5 per cent., by another 12.2 per cent., of the total waste production, and often the fact must be faced that even this amount is not finally disposed of, for after the grease has been extracted the crematory may have to be resorted to for the disposal of the residuum.

Reduction is, after all, closely allied to "picking" and "sorting," although done in a mechanical way, and has been aptly characterized as "an attempt to save something which is not worth saving."

4. *Cremation* is now practiced in about one hundred American towns, and it is being considered by at least one hundred more. It offers, to the hygienist at least, an ideal solution of the problem, and the limits of its possible application have as yet by no means been determined. While in England the crematory generally cares for the ashes, rubbish and garbage, it is common practice in America to cremate only the two latter classes, hence, we have immediately a radical difference in the problem as presented to the two countries. It cannot be denied that England has given this question more earnest study and applied a greater amount of engineering skill to its solution than is the case with us. This is natural, as in the first place, the need is greater, population is more dense, and when the garbage is not promptly removed, the health of the public is threatened to greater degree.

Crematories, or "destructors," as the Englishman calls them, were introduced abroad more than 25 years ago, while the first domestic experiment made by a municipality was in 1887; consequently, the English apparatus has gone through a longer period of development and improvement. Yet there is no desire to belittle the attainments of the English sanitary engineers, whose labors have

ingenious of the dust interceptors consists of an annular chamber, through which the smoke is forced with a whirling motion, depositing the dust by centrifugal force in pockets in the walls.

The English destructor has been so closely correllated with the power plant that in some cases its primary object has become secondary or incidental. As far as the sanitary operation is lost sight of and the question of profit predominates, and precautions which tend merely to prevent nuisance and which bring no income are overlooked or neglected, the operation of the plant becomes to that extent a nuisance. Instances of this kind have given the cremator of refuse abroad the same sort of backset which has been sustained at home through the frequent failures of crematories designed by ingenious mechanics without engineering skill or experience, and based upon false principles. It will, perhaps, be a tribute to our Yankee ingenuity, though it will give the engineer cause for thoughtful consideration, to mention that more than 150 crematory patents have been taken out by American inventors. Scarcely a half dozen of these systems are in successful operation to-day.

It may not be out of place just here to give a brief *résumé* of what has been accomplished on both sides of the water.

In some of our home cities operating crematories where fuel and labor are cheap the garbage has been continuously destroyed at 17 cents per ton. In others, the cost has run as high as 40 cents, 45 cents and even 50 cents; but 35 cents per ton may be taken as a fair average. The cost of destruction of foreign waste, averaged from the results obtained by six of the representative English designs of the most improved type, is 22 cents per ton. The average value of the steam produced, per ton of refuse cremated, at the same six plants, is 13 cents, leaving the net cost of destruction 9 cents per ton, as opposed to 35 cents in America. But consider this: the average production per capita per day is 3 pounds of waste, of which .5 pounds is garbage. This would be in a city of, say, 200,000 people, 300 tons of municipal waste, 50 tons being garbage. Now, disconsidering the cost of collection and hauling, which would be about the same in either case, the English plant has 300 tons of mixed refuse to dispose of daily at a cost of 9 cents per ton; the American plant 50 tons of garbage at 35 cents per ton, amounting respectively to $27 and $17.50 per day, a balance of $9.50 in favor of the American method. Furthermore, consider the disposal of the residuum, which at the crematory will average 5 per cent. (or 2½ tons), by weight, of the material received, and 30 per cent. (or 90 tons) at the destructor. In either system it is *possible* to dispose of

this in isolated cases at a profit to partially offset the cost of destruction, but this is too uncertain a feature to be reckoned on.

A further debit to the English operation account is found in the fact that from 15 per cent. to 40 per cent. of the steam produced is consumed by the forced draft apparatus necessary in the operation of this style of plant. The cost of the initial installation has been left out of the question entirely, while as a matter of fact it would amount in the case of the destructor to 100 per cent. more than the cost of the crematory.

There is probably no other branch of engineering in which theoretically like conditions produce such widely differing results. Many contingencies are responsible for this, but one of the chief causes is the class of labor it is necessary to employ, which is especially troublesome in steam-raising plants, on account of the machinery to be operated and cared for.

One of the most interesting phases of this entire question is that of steam production, which hinges directly upon the calorific value of the refuse. This, in turn, depends upon the character of the refuse, the season, state of weather and many other circumstances. It is also largely governed by the kind of fuel used by the householders, and its market price; for where fuel is expensive, it is naturally more carefully used than where it is cheap, and the refuse has a correspondingly lower percentage of unburned material.

It is estimated that the refuse of English towns within, say, 60 miles of the coal fields, has an evaporative value equal to 20 per cent. of its weight of coal. Of course, there is a wide variation not only in the different localities, but at different times in the same places. Ordinarily, 1 pound of refuse burned under forced draft will evaporate from .5 pounds to 2.25 pounds of water (an average equivalent of about 80 horse power per ton of refuse per hour).

Test runs frequently show an evaporation of 1.5 pounds to 2.5 pounds per pound of refuse, but taken on a continuous run throughout the year, an average of pound for pound is about as good as can be expected, and rather better than is obtained in most instances. A sufficient number of tests and analyses of American refuse have not yet been made to determine positively what its calorific value may be. Domestic ashes in New York City contain from 20 per cent. to 40 per cent. of unburned coal, while those from factory plants carry practically none.

The production of steam power in the cremation of organic garbage alone has not yet been developed to any marked extent. More or less preliminary experimenting has been done along this

line, and some tolerably satisfactory results obtained, but they are not sufficiently general or typical to serve as a basis for predictions on what can be done at any particular point with different classes of refuse.

An interesting study is afforded by some of our local towns which burn gas and oil exclusively as fuel. It may be reasonably inferred that the refuse from such places would be highly combustible, as there is little economy to the householder in burning his dry waste; and, in fact, there is a greater quantity of this material available, but as it consists very largely of light rubbish, waste paper, boxes, etc., it is a question how its value as a fuel compares with that of more stable refuse, carrying even the average precentage of unburned coal. This is one of the many unknown factors in this problem.

The disposal of the residuum from crematory and destructor plants has been touched upon above. Crematory ashes, being fine and light, are not suitable to structural work, but in most cases have valuable fertilizing properties. Frequently, the sifting necessary to remove such foreign matter as tins, broken crockery, old metal, etc., absorbs what profit there might otherwise be in marketing them, but in localities where there is an active demand for the entire production, they can be profitably handled, or at least be made to bring in enough to pay for their disposal.

As the production of clinker from destructor plants is much heavier, its disposal is a proportionately more serious and difficult task. Being vitreous and entirely innocuous, if properly burned, this clinker is valuable material for making roads, mortar, concrete, paving flags, and even bricks; but, owing to the frequent lack of demand, does not always find a ready sale and often becomes such a burden that the city must pay to have it carted away. The little town of Bradford, for instance, spends $5000 a year for its removal.

It is estimated that if all of the clinker from existing destructor plants could be made use of, its value per annum would be $450,000 for brick and tile, or $200,000 for concrete, but the grinding, working and marketing of the material seems to be more of an enterprise than many cities are disposed, or fitted, to undertake.

Representative tests of the ultimate crushing strength of concrete made at the Bradford destructor plant show its value to be 128.03 tons per square foot for a mixture of Portland cement and destructor clinker 1:3. The highest value obtained for similar mixtures of granite, bluestone and Yorkshire stone concrete were respectively 199.64 T., 335.57 T. and 411.01 T. One sample of the

granite concrete ran as low as 85.1 T. per square foot. A general average of the stone concretes was 176.62 T.; of the clinker concrete 124.26 T. Clinker brick made of a 10 per cent. mixture of hydraulic lime were shown 50 per cent. stronger than ordinary building brick. The manufacturing cost of this clinker brick is said to be about $3.50 per thousand.

One of the most important advantages of the crematory and destructor systems is that of being able to locate the plant in practically any part of a city, without offense to its neighbors. The cost of installing the plant has to be met but once, while the expense of hauling material goes on forever. Every cent that can be saved, therefore, out of this fixed expense is well worth saving. Scores of cities are paying so much to have their garbage hauled out of the corporate limits, that for the same amounts they could install, operate and maintain crematory plants, which would pay for themselves in five or ten years. It has frequently been found that the entire expense of operating and maintaining a crematory near the center of population, and of collecting and delivering the garbage, is less than was formerly paid for hauling alone. An instance of this kind is the experience of Memphis, where four crematories were installed in different parts of the city, making the average haul probably not more than a mile.

The collection and cremation of the entire garbage production of the city, including labor and fuel at the crematories, is now accomplished at one-half the previous cost of hauling the garbage away and dumping it into the Mississippi.

The reasonable disposal of the special classes of refuse mentioned in the general ramification will be just touched upon before closing.

V. *Dead Animals.*—Bodies of large animals, especially horses, are frequently disposed of at a profit at rendering establishments, but when this cannot be done, they should be cremated, and cremated promptly. It is here that many cities are blameworthy, in failing to make prompt collections of dead animals, which become exceedingly offensive, particularly in warm weather, if not removed at once.

Burying is a suitable means of disposal in small places, but is not satisfactory for a town of any size, and incineration is commonly practiced.

V. *Night-Soil.*—Nearly every city has a certain proportion of its residences outside of the district covered by its sewer system. The disposal of the excreta from these is an urgent problem. It cannot be safely thrown into waterways, is very offensive if cast

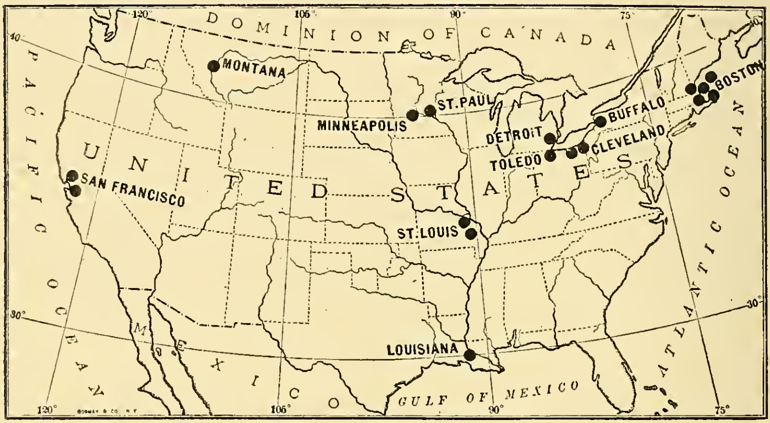
upon lands, impractical as a fertilizer, cannot be treated by the reduction process, and but one solution remains—the crematory.

VII. *Hospital Refuse.*—There can be little argument over this question. No sanitarian will deny that the proper treatment for such highly infectious refuse as is usually produced by hospitals, consisting not only of garbage, but bandages, amputated limbs, etc., is to destroy it by intense heat and preclude any possibility of spreading the infection.

VIII. *Trade Refuse.*—The question of disposing of this class of waste must be governed entirely by its physical character, which depends upon the process or manufacture of which it is a by-product. Sometimes of intrinsic value, again valueless, at others suitable only for a filler, it occasionally has a distinct fuel value, and may be utilized to good effect in supplementing the work of the regular power plant.

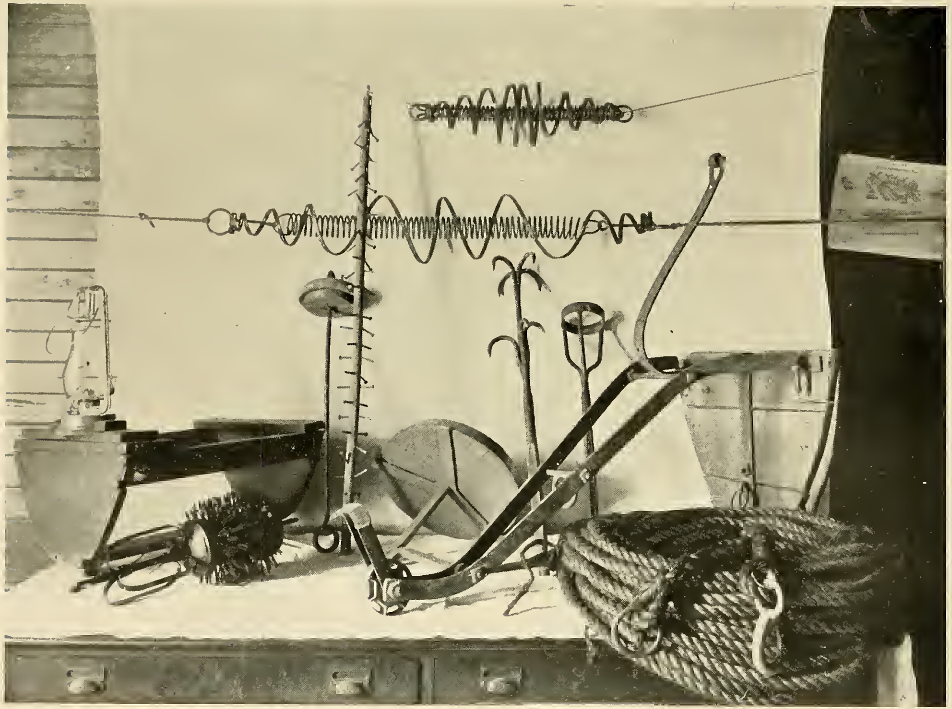
The disposal of sewage sludge is an open question: It is cremated with difficulty, and this does not appear to be the ideal method, at least in furnaces as now designed and operated.

As will readily be seen from the foregoing, this branch of engineering, at all events in the United States, is but in its infancy. Yet the importance of the work, in health to the public, in economy to the municipality, and its future possibilities, make it a subject which should appeal to every thoughtful and progressive engineer.



MAP

Showing the locations of the Societies forming
THE ASSOCIATION OF ENGINEERING SOCIETIES.
(Each dot represents a membership of one hundred, or fraction thereof over fifty.)



Sewer-Cleaning Implements in Use in Newton, Mass.

Journal of the Association of Engineering Societies, Vol. XXXIII, No. 4, October, 1904.

To face page 222.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIII. NOVEMBER, 1904. No. 5.

THE MAIN INTERCEPTING SEWERS OF CLEVELAND, OHIO.

ADDRESS OF WALTER C. PARMLEY, RETIRING PRESIDENT OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club at its Annual Meeting, March 8, 1904.*]

OWING to the fact that almost from its very inception until the first of the present calendar year, your retiring President was intimately connected with the designing and constructing of the intercepting sewer system for the city of Cleveland, the present time and occasion seem opportune for rehearsing some of the history of this important undertaking and presenting some of the engineering features and problems connected with it.

Like all cities, Cleveland has had a sewerage problem of its own to solve. Part of the city lying upon comparatively level or very slightly rolling upland bordering on Lake Erie and part in the low-lying valley of the Cuyahoga River, which cuts the city from north to south into two portions, each of these parts presents a set of problems of its own, and from the standpoint of our intercepting sewer system a third and very serious problem by reason of the elevated portion of the city being thus divided.

The original city was in the valley, only slightly above the lake level, and upon the adjacent easterly plateau. As each portion grew and the necessity of sewerage arose, sewers were built according to the local need and leading by the most direct routes into the river or lake. Gradually there was thus developed a low-level area of sewers and a high-level area, each necessarily separate and distinct from the other. Finally, as the city developed metropolitan pro-

* Manuscript received August 1, 1904.—Secretary, Ass'n of Eng. Socs.

portions, the necessity of laying storm water mains became a pressing one, and old and undersized trunks were rebuilt or new sewers intersecting the lines of flow of the old sewers were so designed as to cut them into sections, thus relieving their congested condition. As illustrating this method of growth by bi-section and reconstruction, Erie Street is now provided with a sewer of the third generation, and the Woodland Avenue sewer, leading into it, was entirely rebuilt, cutting off other sewers, so that, for a large area, the sewerage has undergone an entire transformation. Then again, owing to the fact that the city has grown beyond the original plans in many drainage districts, new outlets have been located differently from what would have been the case if they had been designed in connection with the older portions. The result of all this is the fact that we have a river and a lake front both highly contaminated with sewage.

Sewers are discharged into the Cuyahoga River at frequent intervals along both sides, and, as the principal sources of pollution, slaughter houses, rendering works, and the refineries of the Standard Oil Co., are located along either the bank of the river or its tributaries there is produced a condition in the lower portion comparable with that of the Chicago River before the construction of the drainage canal.

For a distance of about five miles along the lake front, extending from west of the waterworks intake to Doan brook, large volumes of sewage are discharged into the shallow marginal water of the lake. Many years ago the dangers of such increasing pollution of the water front began to be recognized, and in 1882 Mr. Rudolph Hering reported to the Council a general scheme of intercepting sewers as the problem at that time presented itself. As the plan was not carried out immediately, the growth of the city made this plan obsolete, one principal feature only of it needing to be mentioned. This plan contemplated discharging the entire volume of the sewage into the lake at Marquette Street. That such a point of final discharge could at that time have been considered is one of the most surprising indications of Cleveland's growth and expansion in the last twenty years.

So urgent had become the necessity for the removal of the pollution from the river and lake front that in 1896, by action of the City Council, an expert commission was appointed to take up the whole subject of improved water supply and the disposal of the sewage of the city. The commission consisted of Messrs. Rudolph Hering of New York, Desmond Fitzgerald of Boston, and George H. Benzenberg of Milwaukee, together with Mr. M. E.

Rawson, then Chief Engineer of the Department of Public Works, and Mr. M. W. Kingsley, Superintendent of the Water Department. This commission was instructed to take up the subject thoroughly, to consider it in all its phases and to devise a scheme whereby pure lake water could be obtained as well as an efficient and permanent removal of the sewage.

Without going into a detailed discussion of the reasons on which they based their final report, a few of the principal objects to be accomplished and the physical conditions of the case may be stated. So long as the sewers were allowed to discharge directly into the lake, even a removal of the intake further from the shore would not insure an uncontaminated water supply, on account of the shallow depth on the margin of Lake Erie and the configuration of the coast line. The high winds, coming from the West, or North, or East, or any intermediate points, roile up the water with its accumulated sediment for several miles from shore. This sediment, being of course highly contaminated, injuriously affects the water supply. The Cuyahoga River being little more than a slack water inlet, the pollution from this source flows out directly toward the water works intake, and some means for removing the sewage from the river must be found.

It therefore seemed obvious that two principal things must be done: (1) to take the water supply at a point much further from shore; (2) to build an intercepting sewer system in such a manner as to intercept the sewage flow of all of the sewers of the city and carry it to some point of disposal so removed that the sewage would not contaminate the water supply. The third project, which was advocated by Mr. C. G. Force, Assistant Chief Engineer, was to build a flushing tunnel about 18 feet in diameter extending, from an intake on the lake shore near the eastern end of Edgewater Park, underneath the western portion of the city, to a point on the Cuyahoga River about 6 miles from its mouth; to erect a pumping station on the lake shore with a capacity sufficient to force a volume of water through this tunnel to the upper reaches of slack water in the Cuyahoga River, such that the entire volume contained in the river between the point of delivery and Lake Erie could be displaced every 24 hours. The expectation was that, if the volume of Cuyahoga River is displaced by a volume of comparatively pure water every 24 hours, its effect upon the water of Lake Erie would be much less deleterious than where it is allowed to stand for some days or even weeks in the river channel before its final discharge. The expense of carrying out this project seemed to be the most serious objection against it, as the cost, for the tunnel, the pumping

station and the necessary terminal works was estimated to be about $1,000,000.

The final recommendation of the commission was to the effect that the water supply should be taken from a point in Lake Erie about 4 miles from shore and as far to the west of the mouth of Cuyahoga River as practical; that the intercepting sewer be so devised as to carry as much of the sewage of the city as possible by gravity to a common outlet about 10 miles to the east of a point on shore opposite the water works intake. It further recommended low level intercepting sewers for all of the valley lying along the Cuyahoga River and its branches; that is, that Walworth run, Morgan run, and Kingsbury run, lying below the level of the gravity system be sewered to convenient pumping stations and there be lifted to the high level system and thus delivered to the one common outlet for the entire city. The sewer commission was divided in regard to the flushing tunnel project; the majority advocating its immediate construction, but the minority reporting in favor of first constructing the water intake system and the intercepting sewer system. It was the belief of the minority that taking the water supply at a greater distance from shore and discharging the sewage into the lake as far to the east as possible would render the construction of the flushing tunnel unnecessary. If, however, this did not prove to be the case, they recommended that the flushing tunnel be then built. As up to the present time nothing has been done toward building the low-level intercepting sewers, I shall dismiss this part of the subject and confine myself entirely to the high level or gravity system.

Following the advice of the commission, the City Council determined to enter upon the construction of high-level intercepting sewers. They established a department of special sanitation, and, as engineer in charge of this department, I have given the past seven and one-half years to the development of the system. While the work is not all constructed, so much has already been designed and built, sizes, grade elevations and the engineering lines permanently fixed, on which the entire work must be carried through to completion, that no great modification can hereafter be made either in that which has been done or in that which is planned.

The commission planned the building of a large interceptor to extend entirely across the lake front of the city, beginning at the western limits at Highland Avenue, and extending eastward so as to intercept the flow from all of the sewers of the west side which discharge into Lake Erie, passing underneath the Cuyahoga valley and river through an inverted syphon about three-quarters of a mile

in length, extending easterly along Lake Street and through streets parallel to the lake, and discharging into Lake Erie some eight miles east of the Cuyahoga River. A branch, extending south from the main interceptor at Ross Street and passing through the entire length of Perry Street to the intersection of Broadway, was contemplated. At this point it was to branch again, one portion extending across the Cuyahoga valley and river in a southwesterly direction through another inverted syphon nearly a mile in length, terminating near the southern end of the Central viaduct. From this point it will extend in a southwesterly direction to about the intersection of Walworth Street and Barber Avenue, at which point it will intercept all of the branches flowing into Walworth run.

The other branch, from the intersection of Broadway and Perry Street, was to extend along Pittsburg road, crossing the Kingsbury valley through inverted syphons, and pass out Broadway to Petrie Street, where it would continue to the south, cutting the drainage of Morgan run and ultimately that of Burke brook still further to the south. A branch was to extend from this lateral to the eastward along the north side of Kingsbury run valley, and terminate at a point about a half mile east of Willson Avenue, taking in numerous sewers en route and at the latter point intercepting the flow from all the upper portion of Kingsbury run.

The commission had laid down some of the different ideas which were to control the construction of the intercepting system, but it left all matters of their development and details to be determined by further study. As a result of this further study, an important lateral begins where the main interceptor crosses Doan brook, and extends in a southeasterly direction along Doan brook valley a distance of about four miles to Cedar Avenue. This sewer, known as the Doan valley interceptor, is the outlet for all of the important and rapidly growing eastern portion of the city.

The map [Fig. 1] shows the main drainage areas which are tributary to the several portions of the high level interceptor and its branches. It is thus seen that the entire city is drained, with the exception of a comparatively small part lying along the valleys. It was, therefore, recommended that the low-level system be not constructed until after the building of the high-level system.

The commission fixed the unit volume of sewage discharge to be employed in designing the system. It was assumed that the maximum rate of flow per capita would be 200 gallons, and, in order to prevent the first and most filthy of the gutter water from the streets discharging into Lake Erie by way of the storm-water overflows, the sewer, as designed for the above unit, should never run more

than half full, the upper half of the sewer being reserved for this first surface flow from the street. It was further assumed that, within the next 25 or 30 years, the population of Cleveland would reach 1,000,000, and the size of the sewer was therefore made sufficient to accommodate this population.

The grade inclination of the main interceptor was fixed at 2 feet per mile, and the commission was undecided as to whether the

FIG. 1. MAP OF CLEVELAND, SHOWING PRINCIPAL AREAS TRIBUTARY TO THE MAIN INTERCEPTING SEWER.

Space within shaded lines indicates area tributary to low-level system.
Arrow-heads indicate the most important inlets to Intercepting Sewer.

elevation of the center of the outlet should be 7.5 feet or 10 feet above base. They recommended that the main outlet be 13 feet in diameter, but, owing to subsequent study of the case and the fact that a considerable area lying still further to the east from that considered by the commission will become tributary to the sewer, the diameter, from Doan brook easterly to the outlet, was increased to 13 feet 6 inches. The elevation of the outlet, as finally determined, is 7.75 feet above base for the center of the sewer, or, 1 foot above base for the invert.

The final location for the intercepting sewer was not determined by the commission. It was expected, however, that the portion east of the river would run along Lake Street to Marquette Street, thence either along the right of way of the Lake Shore and Michigan Southern Railway easterly, or, by some other direct location to be secured, to Ansel Avenue. After crossing Doan brook, it was to follow the Lake Shore boulevard to the outlet, which was expected to be a short distance east of Euclid Beach Park. It was found subsequently that the sewage outlet could not be made quite so far to the eastward, and a tract of about 6 acres, on the shore of the lake at the foot of Adams Avenue in Collinwood, was purchased by the city for outlet works. This point is distant from the Cuyahoga River about 8½ miles.

It was found later that certain changes would be necessary in the location. On account of the great cost of the work per lineal foot, as direct a route as possible was desirable. Negotiations were therefore begun with the Lake Shore Railroad, which finally resulted in an agreement whereby the city obtained the right of way along the northern portion of their right of way and extending easterly from Gordon Park to a point about 1950 feet east of Doan Street, a total distance of about 6000 feet. The consideration for these rights was $13,986.52.

Another important change was made easterly from this latter point. It was found that, where the sewer would cross Nine Mile creek at the Lake Shore boulevard, expensive retaining walls would have to be constructed, and this, together with the almost certain litigation with adjacent property owners, which would result if it were attempted to build a sewer by this route, caused the city to seek a new location. Additional rights were therefore secured from the railroad, extending easterly from the right of way already acquired and over adjacent land parallel with the railroad, to where Gilbert Street meets Coit Avenue, immediately to the north of the railway. From this point, rights were obtained to the east and north in Gilbert Street to an intersection with the Lake Shore boulevard.

In obtaining this location it was necessary to enter into an agreement with the village of Collinwood, and to obtain a modification of the terms of the original contract between the city of Cleveland and the village of Collinwood. By this contract, in consideration for the right of way, the city of Cleveland agreed to construct, and to allow the village of Collinwood the exclusive use of, one of the terminal discharge pipes into Lake Erie. The village insisted upon this concession because their sewage plane is about ten feet lower than that of the city of Cleveland, and, if the two flow-lines

are not kept separate, the sewage of the main intercepting sewer would flow back and flood the sewers of Collinwood. Although the cost of building the $3\frac{1}{2}$ or 4-foot pipe line into Lake Erie, thus made necessary, would involve extra expense, it seemed the only practicable thing to do. By this location the length of sewer was increased some 930 feet over the location by way of the boulevard. Up to the present time I see no reason to regret the selection of this route, but, as will be noted further on, subsequent experience in the construction of the sewer has shown that it would have been more economical for the city to purchase a right of way parallel and adjacent to the railway on the north side than to have attempted to build the sewer on land owned by the railway and under a contract whereby the railway could impose conditions upon the city in the construction of the sewer.

The first and most important item, in connection with carrying out of the intercepting project, was the building of the sewer in Walworth run, which is technically more a main storm sewer than a portion of the interceptor at all. Plans were therefore first perfected for this portion of the work, which was under actual construction from early in 1897 until the spring of 1903, and upon which, although in cost exceeding $800,000, the final settlements have not yet been made. It is not necessary, however, at this time, to describe this work in detail as it has already been discussed before this Club.

On account of the urgent need in the western portion of the city, which had formerly been the village of West Cleveland, and which territory was dependent upon the construction of the intercepting sewer for its outlets, it was determined to build the western extremity of the interceptor first. Here the location under agreement followed the Lake Shore Railroad for a distance of about 4000 feet from Alger Street to Lake Avenue. The diameter of this section of sewer is from 6 feet to 8 feet. This section was built during the season of 1897 by Louis Fahey, at a cost of about $30,000. During 1898 and 1899 the interceptor was continued westerly along Lake Avenue as far as Lower Street.

There are no interesting features in regard to the construction of the sewer itself. At the intersection of Lake Avenue and the Lake Shore Railroad, however, the Desmond Street trunk sewer, the Lake Avenue sewer from the east, and the intercepting sewer from the west, converge. The problem of the separation of the sewage from the storm flow became quite complicated, as will be seen by the plans (Fig. 2). The portion of the interceptor west of the railroad carries the full volume of storm water as well as of

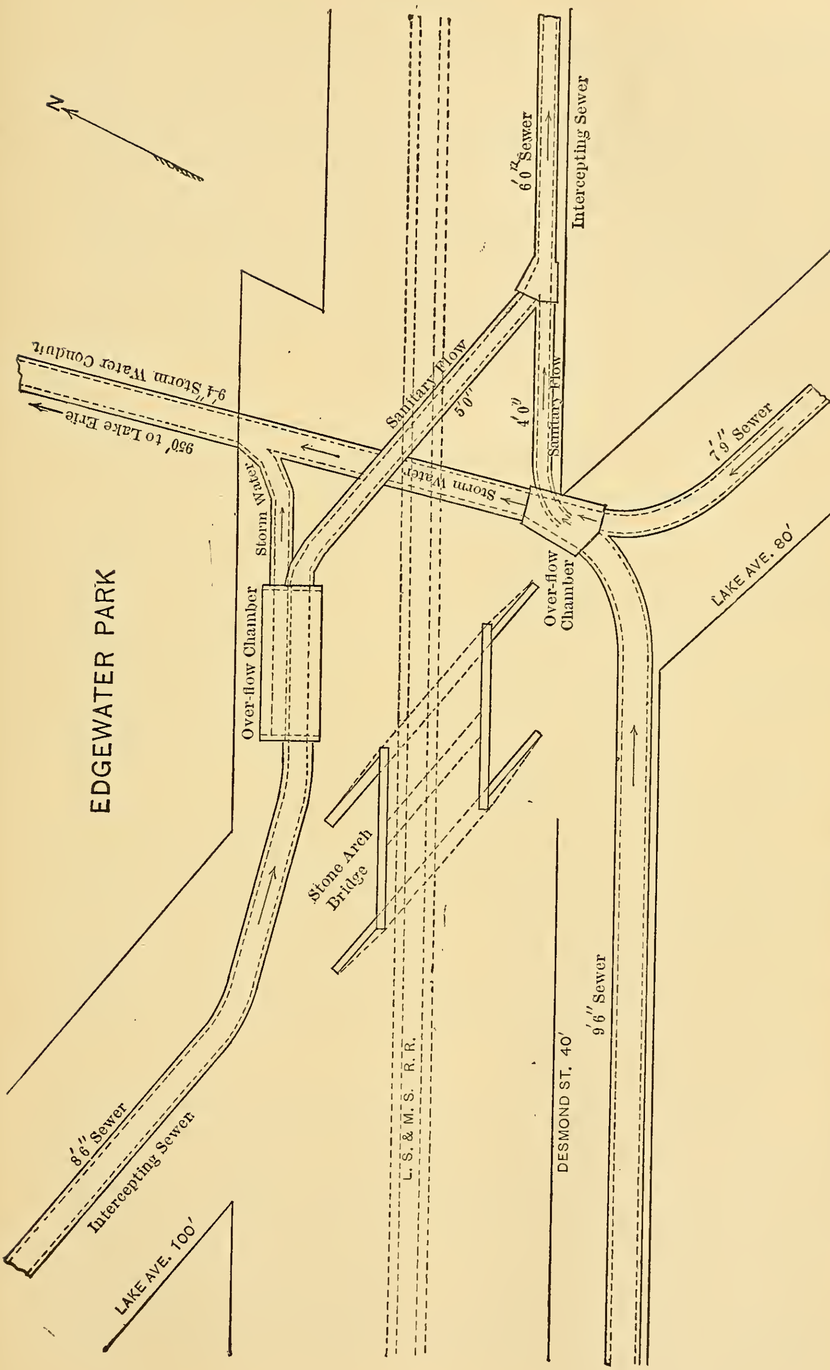


FIG. 2. LOCATION OF STORM-WATER OVERFLOWS AND SANITARY FLOW SEWERS AT THE INTERSECTION OF THE L. S. & M. S. R. R. AND LAKE AVENUE.

sewage, and at the points of intersection of this portion with the main sewer in Lake Avenue from the east, and with the Desmond Street sewer, overflows were constructed in such a manner that the flood water would pass through a 9-foot 4-inch storm-water outlet tunnel underneath Edgewater Park and discharge into Lake Erie. Where the Desmond Street sewer and the Lake Avenue sewer east of the railway intersect, a chamber junction was built, and the invert provided with a deflecting weir or dam in such manner that the sewage is carried through the side of the structure into the intercepting sewer, the flood waters passing over the dam and down a steep incline into the Edgewater tunnel. The diameters of the Desmond Street and Lake Avenue sewers are respectively 9 feet 6 inches and 8 feet 6 inches.

The overflow from the interceptor, in Lake Avenue west of the railroad, is so constructed that the sewage passes through a 5-foot tunnel diagonally underneath the embankment of the railroad, joining with the interceptor about 100 feet down stream from the chamber junction first described. Where the flow comes into the chamber the sewer is 8 feet 3 inches in diameter, and the storm water flows sideways over a weir 50 feet in length, passing down the storm overflow channel into the Edgewater tunnel. The tunnel, conveying sewage from this chamber to the main intercepting sewer through and underneath the railroad, passes diagonally over the inclined portion of the Edgewater tunnel where it approaches the chamber junction on the Desmond Street sewer.

The portion of the Edgewater tunnel underneath the railway was built under one of the Louis Fahey contracts in 1898. The tunnel was in very wet, treacherous quicksands, and was built with great difficulty, and, in order to prevent serious settlement of the railway, large masses of brick masonry were built into the cavities and pockets that formed over the arch. The network of trunk and intercepting sewers, converging at this point, was completed about 1900. The complicated sewer connections at this point are well illustrated by the plans.

A short extension of the intercepting sewer between Alger Street and Gordon Avenue was constructed in 1898, together with an overflow sewer extending down Gordon Avenue to the Lake Shore Railroad, following easterly along the Lake Shore and Michigan Southern Railway to Waverly Street, at which point it turns to the north and empties into the west basin of the harbor. At the west side of Gordon Avenue an overflow chamber, similar to the one on the Lake Avenue section just described, was built. The cost of the portion of the intercepting sewer system from Gordon Avenue west was about $200,000.

It will be noted that I have described storm-water overflows from the intercepting sewer. An intercepting sewer, strictly speaking, should have no storm-water overflows. The reason for this may readily be seen by considering the fact that, if combined sewage and storm water were to be discharged into an intercepting sewer of indefinite length, overflows being provided at those points where the sewer would be liable to surcharge, a point would soon be reached where there would be no difference in composition between the sewage contained in the intercepting sewer and that flowing in from the lateral mains. Since, however, the west side sewers are near the upper end of the intercepting system, the effect of storm overflows directly from the interceptor is not as objectionable as they would be nearer the outlet. It was, however, determined that, at no point in the system east from Gordon Avenue, would overflows be constructed.

To avoid the objectionable overflow of sewage from the interceptor, the overflow chambers are built on the combined sewers before the connection with the interceptor is made. Hence, only the sewage of the storm sewers, together with the proper ratio of street washings, is allowed to enter the main intercepting sewer, and the sewage, when once in the interceptor, is there confined until it reaches the final outlet. In this manner only will the interceptor truly intercept the sewage, and in the best manner prevent the pollution of the water front.

It was not until the autumn of 1900 that the work of designing the main interceptor outlet was begun in earnest. Plans for four different sections were developed during the winter and spring of 1900-1, and contracts were let in the summer of 1901. The first contract to be awarded was that extending from the point on the shore of Lake Erie off Adams Avenue, upon land purchased by the city for the terminal, and extending westerly along the lake shore a distance of about half a mile to Gilbert Street.

In view of the rapid increase in price of labor as well as all of the materials used in sewer construction, I gave considerable study to determining the most economical construction for this work. At best, the outlay would be enormous, but even a small percentage of saving in the aggregate would represent many thousand dollars of saving to the city. A concrete and steel structure was finally decided upon, but plans were also made for a concrete brick-lined section, and bids were invited upon each. Fig. 3 shows the location, profile, and sections of these structures. The bids were received on June 25, 1901, the lowest bid for the masonry section being $108,630.28 and that for the concrete and steel section $85,025.84, a resulting

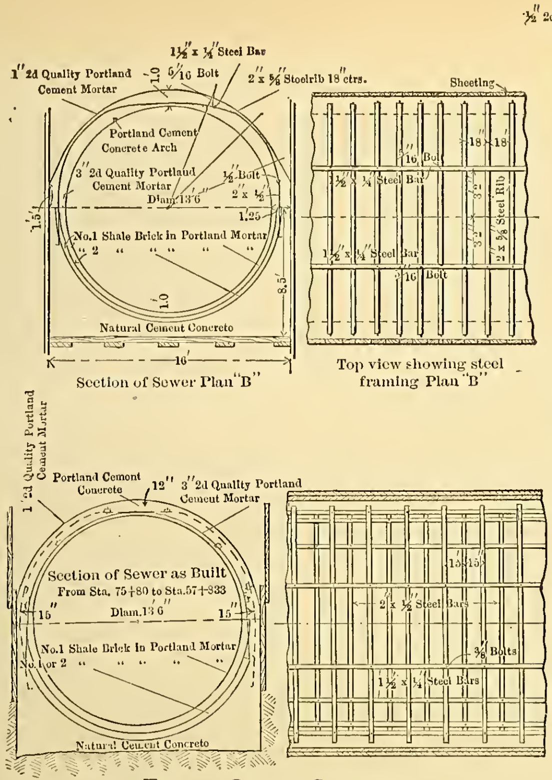


FIG. 4. OUTLET SECTION.

APPROXIMATE QUANTITIES PER FOOT OF SEWER.

Brickwork	0.63	cu. yd.
Portland Cement Concrete	0.90	"
Natural Cement Concrete	1.65	"
Excavation	14	"
Iron and Steel	82	lbs.
Grillage	63	ft. B. M.
Sheeting and Bracing	135	" "

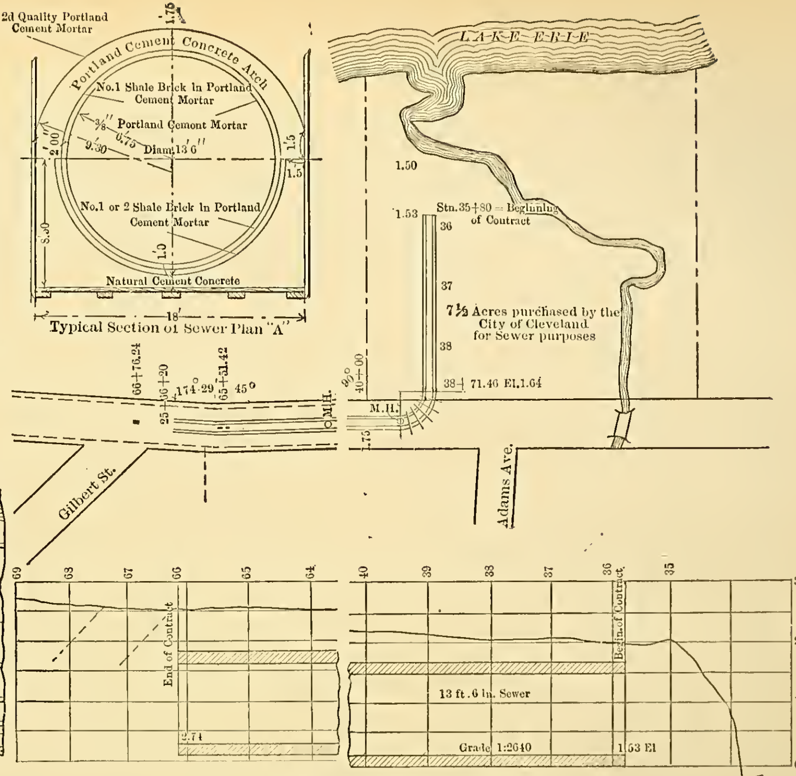


FIG. 3. OUTLET SECTION.

APPROXIMATE QUANTITIES PER FOOT OF SEWER.

Brickwork	0.932	cu. yd.
Portland Cement Concrete	1.74	"
Natural Cement Concrete	2.55	"
Excavation	17	"
Grillage	69	ft. B. M.
Sheeting and Bracing	135	" "

saving, in the cost of the concrete and steel section over that of the masonry section, of nearly 22 per cent.

The work was accordingly let to Messrs. Beers & Doolittle for the concrete and steel sewer; but, on account of delays in executing the contract and getting machinery ready, the date of beginning of the actual construction of the sewer was April of 1902.

So successful had been the result of the bidding upon the first section of the work, that a similar method was followed in the letting of the next two sections. These sections were not continuous with that first let, for the reason that there was some uncertainty as to the right of way for the portion immediately to the west of the Beers & Doolittle contract. The second bids therefore were for the portion extending from a point on the Lake Shore and Michigan Southern Railway from Doan Street to a point 1750 feet easterly. The plan of the sewer was the same as that shown in Fig. 3, but the depth of excavation in places was over 40 feet. Bids for this work were received July 2, 1901. The lowest bids were made by Mr. Christian Burkhardt, at $103,297 for masonry construction, and $80,131 for the concrete and steel; the difference being $23,166, or a saving of over 22 per cent. The bids were received for the next section, extending from Doan Street westerly to Lewis Street, on a section where the excavation was all from about 38 feet to 44 feet deep. The figures of J. Connelly & Son the lowest bidders, in this instance, were $128,891 for the concrete and steel as against $160,498 for the masonry structure, or, a saving of about 19.7 per cent. Contracts were accordingly awarded to these firms on a basis of the concrete and steel structure. Later, however, the concrete and steel section, with the consent of the contractors, was changed to that shown in Fig. 4, in which a more complete inner and outer metal skeleton was provided.

The fourth section for which bids were received was a continuation of the sewer westerly from Lewis Street and across Doan brook valley to Ansel Avenue. As the saving in the cost of the work, by adopting concrete and steel, was so great, it was decided not to receive bids for masonry structures at all. Plans and specifications were then based entirely upon concrete and steel similar to that already contracted for, and the work was accordingly awarded to the Clements Construction Co. upon bids received July 16, 1901, for $176,190. The beginning of the construction work on all of these sections was delayed until the spring of 1902 in a similar manner to that on the Beers & Doolittle contract.

The final location of the right of way having been determined, and in order to hasten the completion of the portion of the main

interceptor from Doan brook to the outlet, during the spring and summer of 1902, four other contracts were awarded, viz, to the Clements Construction Co. for the portion on Gilbert Street from the Lake Shore boulevard to Shipherd Street; to Beers & Doolittle on Gilbert Street and along the Lake Shore Railway from Shipherd Street to Coit Avenue; to Messrs. J. Connelly & Son along the

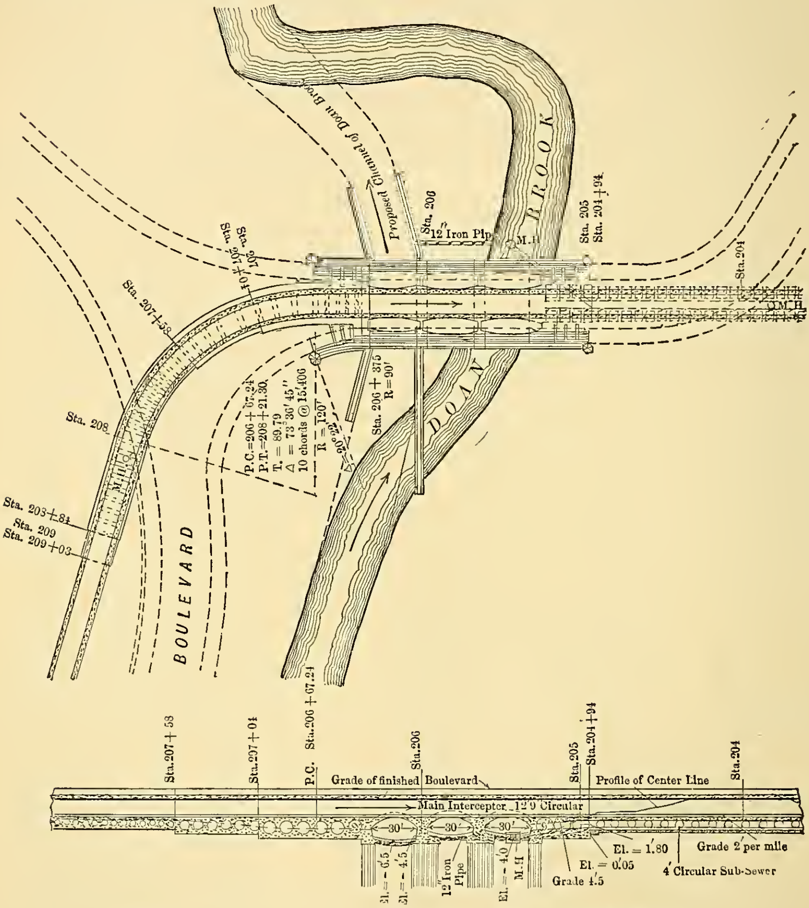


FIG. 5. DOAN VALLEY CROSSING OF MAIN INTERCEPTOR.
Scale 1 = 1440.

Lake Shore Railroad from Coit Avenue to Eddy Road, and to John Wagner & Son from Eddy Road west to a point 1750 feet east of Doan Street connecting on to the portion of the work awarded to Burkhardt. These four contracts were for concrete and steel sewers, and the aggregate bids were about $434,000. During the season of 1903 work was prosecuted upon all of these sections with the excep-

tion of the Burkhardt contract, resulting at the present time in almost completing the first Beers & Doolittle contract on the Lake Shore boulevard and the practical completion of their second section from Shipherd Avenue to Coit Avenue, including the Nine Mile creek syphon, and the entire completion of the Clement contract on Gilbert Avenue from the boulevard to Shipherd Avenue;—the other sections being in a partial state of completion.

The section from Lewis Avenue to Ansel Avenue was located and contracted for by way of the route passing across the valley on the south side of the Lake Shore and Michigan Southern Railway. Before construction was actually begun, however, the chief engineer decided that it would be advantageous to build the sewer upon the north side of the railway, and accordingly issued instructions to the contractor to follow the new location upon that side.

In the meantime, on September 1, 1902, Cleveland experienced a phenomenal downpour of rain, said to have been the heaviest in 40 years. In consequence of this fact and the necessity made apparent for ample water way, the culvert for Doan brook, which passes underneath the intercepting sewer, was greatly increased from what was first contemplated. The capacity of the culvert, as finally designed and built, is for 3000 cubic feet of water per second. The culvert consists of three 30-foot water ways, spanned by 3 parabolic arches with low abutments. The arrangement of the lower driveways of Gordon Park is such that one of the boulevards passes from the west side to the east side of the valley across and on top of the sewer structure. The culverts are therefore made 60 feet long, terminating in substantial and ornamental parapet walls, buttresses and copings. Fig. 5 shows the general plan of this work, and Fig. 6 a view during construction.

The grade line of the interceptor is several feet above the bottom of Doan brook valley, and it was therefore necessary to carry the foundations down to solid clay. Transverse circular forms were imbedded in the foundation, thus reducing the amount of concrete required, and at the same time decreasing the pressure per square foot upon the clay. This portion of the work is practically completed and is well shown by the plan, Fig. 5, and by Figs. 17A, 17B and 17C.

An interesting feature experienced may be mentioned in connection with these culvert arches. The parapet walls are stone faced, with Portland cement concrete backing, and with anchor rods embedded. The arches themselves, however, consist of unarmored concrete. After the filling for the boulevard was deposited on each side of the sewer and inside of the parapet walls, it was noticed, in

several of the arches, that there was a slight tipping out of the parapet walls, resulting in a crack running around the arch parallel to the face and about 6 or 8 feet back from it. This doubtless resulted from the fact that the weight of the parapet wall is greater than that of the earth backing, and caused a corresponding increase in the deflection of the arch at the ends. The outward pressure of the earth backing tended in the same manner to push the parapet out and so produce a crack. As soon as this was discovered,

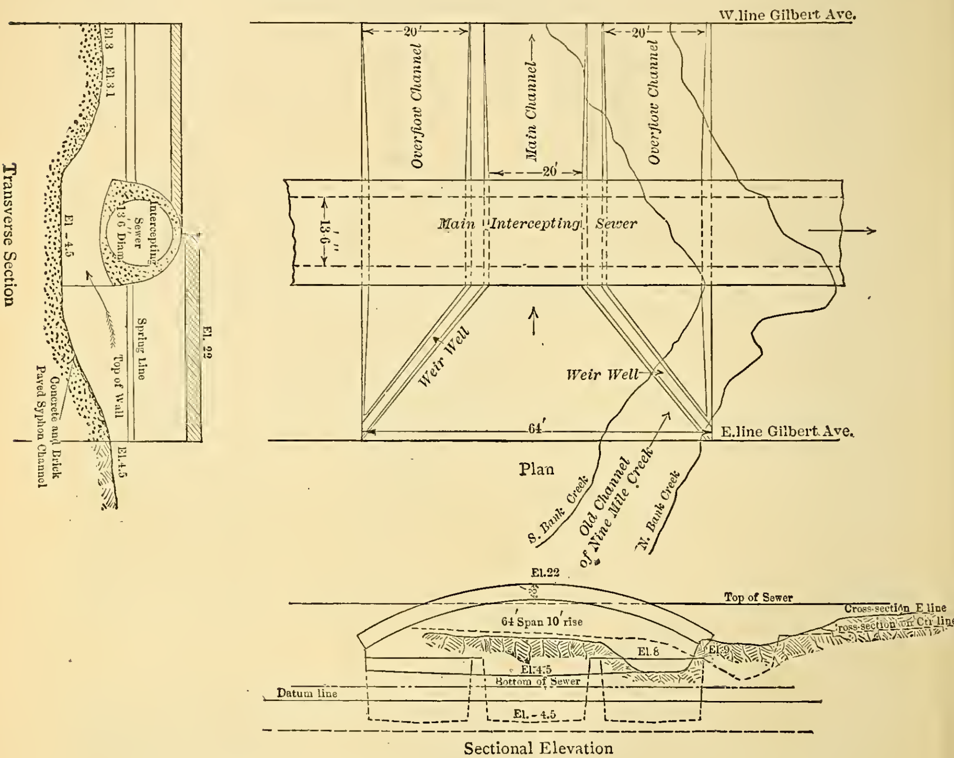


FIG. 7. MAIN INTERCEPTING SEWER CROSSING AT NINE-MILE CREEK.

channels, at right angles to the face of the arch, were cut in the intrades. These channels were cut about 3 inches wide and 2 inches deep and were about 6 feet long. In these channels were imbedded $\frac{1}{2}$ inch x 2 inch steel bars in Portland cement mortar. Seven such bars were built into each end of the arches, and it is believed that no further damage will result.

Another interesting detail occurs where the sewer crosses Nine Mile creek, as shown in Fig. 7, which gives the plan of the intersection. The grade line of the sewer is about on a level with the

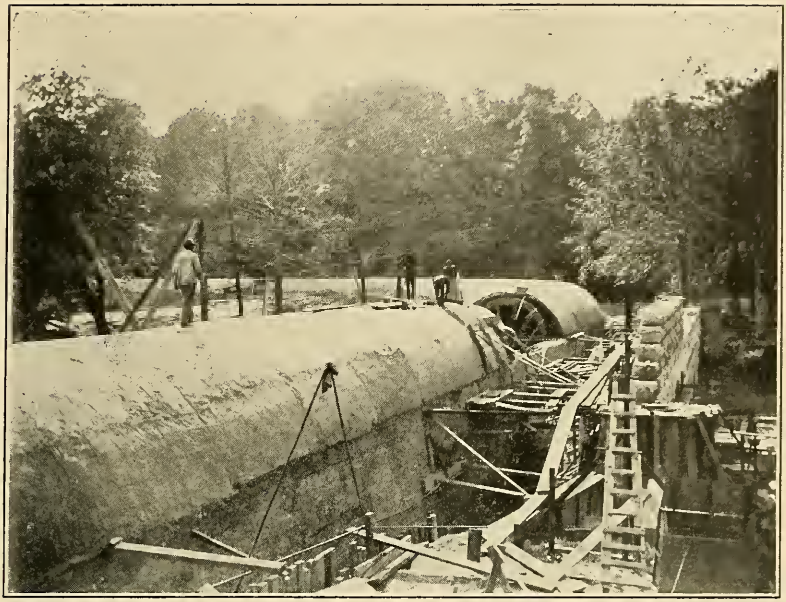


Fig. 6. Showing 12′ 9″ Main Intercepting Sewer Crossing Doan Brook Valley. Park Boulevard is Carried Across the Valley on Top of the Sewer.

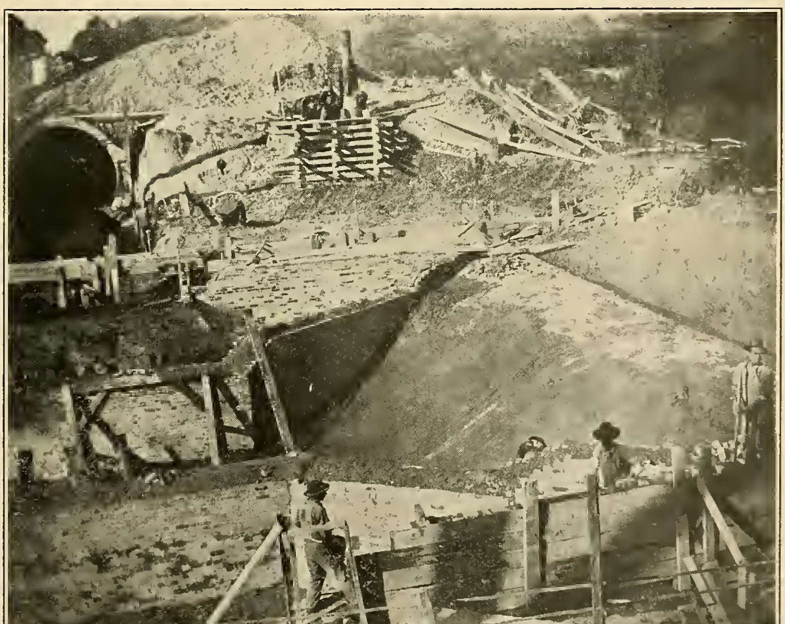


Fig. 8. Showing Channel of Approach to Nine-Mile Creek Inverted Siphon.

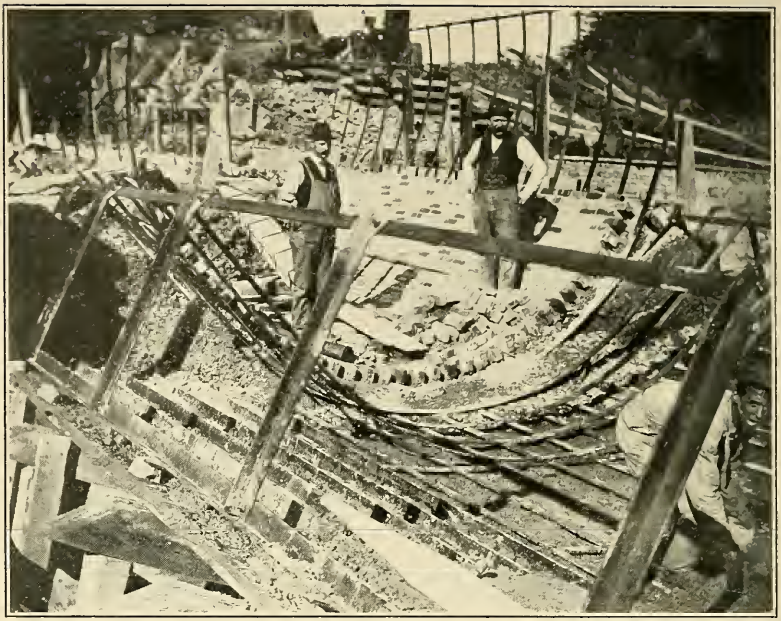


Fig. 9. Showing Tubular Bridge Construction of 13′ 6″ Sewer at Nine-Mile Creek Crossing.

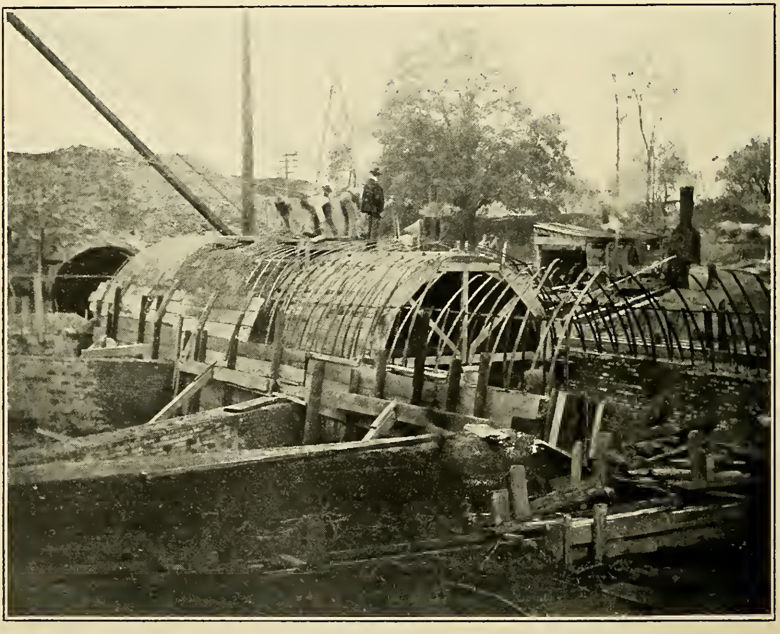


Fig. 10. Showing 13′ 6″ Sewer Passing over Nine-Mile Creek.

channel of the brook, and it was therefore necessary to carry the brook underneath the sewer in an inverted syphon. Three 20-foot channel ways were provided. At the inflow end, however, oblique walls, extending diagonally across the two side channels, are constructed in such a manner as to converge all of the flow through the middle channel, except during excessive floods, when the water will flow over the oblique walls into the two side passageways.

On the down stream side the water is allowed to pass through each channel separately. The whole structure is made 80 feet long in order to extend the entire width of Gilbert Street, and on the down stream side is arched over with three 20-foot concrete and steel arches. On the up-stream side it was necessary to build a single-span arch of about 80-foot span, between abutments, in order to avoid obstructions to the inflowing water. Along the up-stream and down-stream lines of Gilbert Avenue, the structure terminates in parapet walls to confine the earth filling which is used to bring the street up to grade.

Steel being imbedded in the bottom portion, to form a lower chord to the structure, and the sewer being completely hooped with steel, it cannot deflect under the weight of the water inside, or the pressure of the earth from without. It thus becomes practically a tubular bridge. The plan, Fig. 7, clearly illustrates this work and it is further shown in the photographs, Figs. 8, 9 and 10. A similar method is adopted for sustaining the interceptor where it crosses Dugway brook, but in this instance the inverted syphon was not necessary.

As already stated, the work of actual construction of the intercepting sewer, east of the river, did not begin until April, 1902, the point of beginning being near the outlet upon land owned by the city.

Some time, of course, was occupied in excavating the trench to the necessary depth, and in connection with this work an interesting thing happened. The ground is a clay which stood with vertical banks until, for a length of something like 300 feet, the excavation had been nearly completed. No sheeting or bracing had been used, as the excavation had been done by means of teams and scrapers with inclines at the ends. At about this time a three days' steady rain occurred, soaking the banks so that they began to cave. Sheeting and bracing were inserted as quickly as possible, but not until the banks squeezed together so as to make it impossible to build the side walls of the thickness planned. On account of the difficulty and cost of setting the sheeting back to the necessary line, the contractors were permitted to proceed with the building of the sewer, with the side walls much thinner than the contract called for, and with the

expectation that afterwards they would dig down on the outside, remove the sheeting and reinforce the sewer. As the contractor's force of men was busy with construction work, this reinforcing was not done immediately, and, with the exception of one small portion, it has not yet been done. Fig. 11 shows actual cross sections of the sewer as it was built and as it is standing to-day, carrying the load (one exception to be noted), without a sign of cracking or weakness. It will be observed that, in many places, the side wall is only 6 inches thick or even less, and the fact that it is holding the earth loads of a 20-foot ditch is a striking proof of the strength of the concrete and steel structure. On the west side of the sewer near the outlet there is one place about 30 feet long, where the brickwork opened along the underside of the top course of brickwork and just below the springing line of the arch. As the width of the invert is somewhat less than 13 feet 6 inches, an examination shows that it

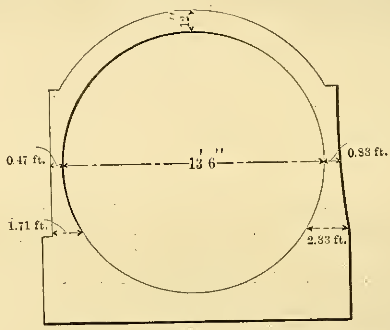


FIG. 11. CROSS SECTION OF INTERCEPTING SEWER.

resulted from the side pressure of the earth forcing in the thin side wall either during or immediately following the construction of the arch and before the centering was removed. As the normal tendency is for the sewer to increase in width at the springing line instead of to diminish, its behavior is evidently due to a weakness of the side wall below the springing line and not to weakness in the arch structure itself.

The general method pursued by the contractors varied only in matters of detail. For the most part cable machinery is used upon the work. The excavation is carried to the required depth and made level transversely. The concrete foundation is then laid, with the proper curve at the bottom, and is carried up to about the level of the bottom ends of the anchor bars. The brick lining is then brought up to about the same level. The anchor bars are suspended to line and grade and to the proper spacing. To accomplish this,

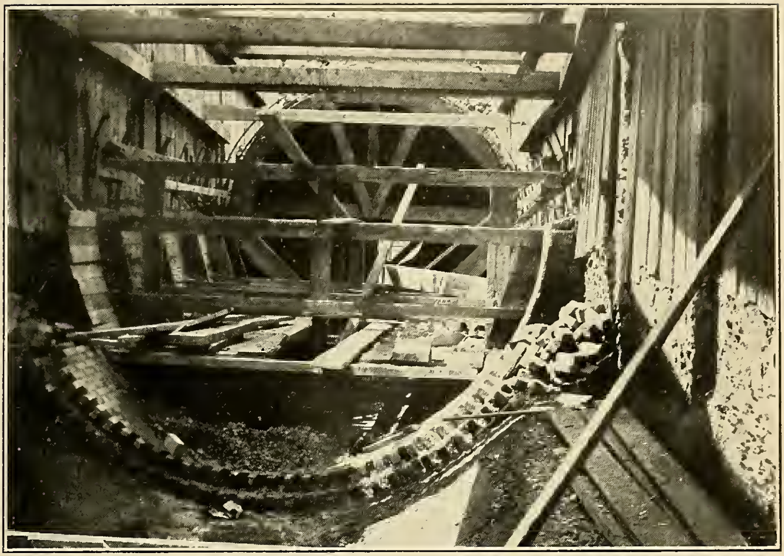


Fig. 12. Showing Formation of Invert and Side Walls of 13′ 6″ Sewer.

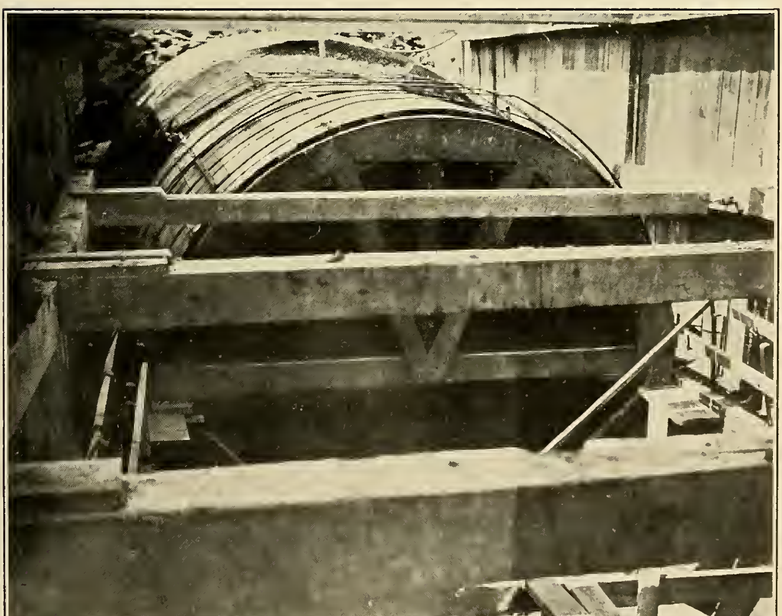


Fig. 13. Arch Skeleton of 13′ 6″ Sewer.

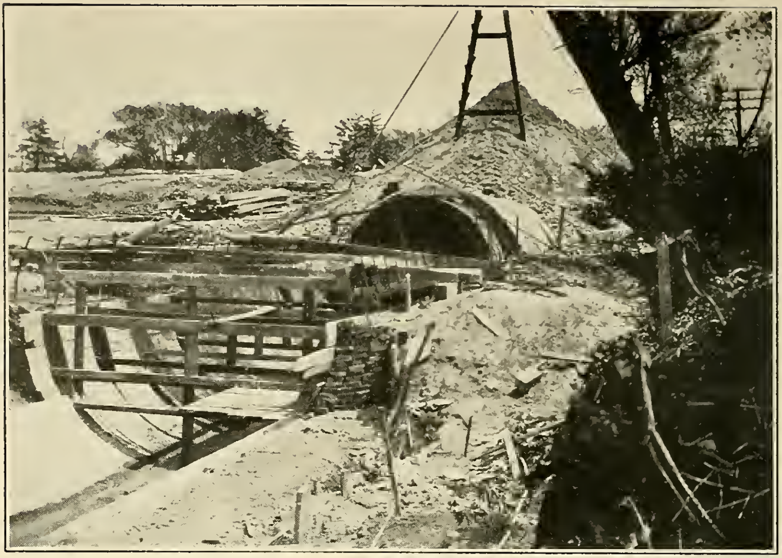


FIG. 14. 13′ 6″ SEWER IN SHALLOW TRENCH AND IN DIFFERENT STAGES OF COMPLETION.

FIG. 15. 13′ 6″ SEWER WITH SKELETON OF ROUND RODS.

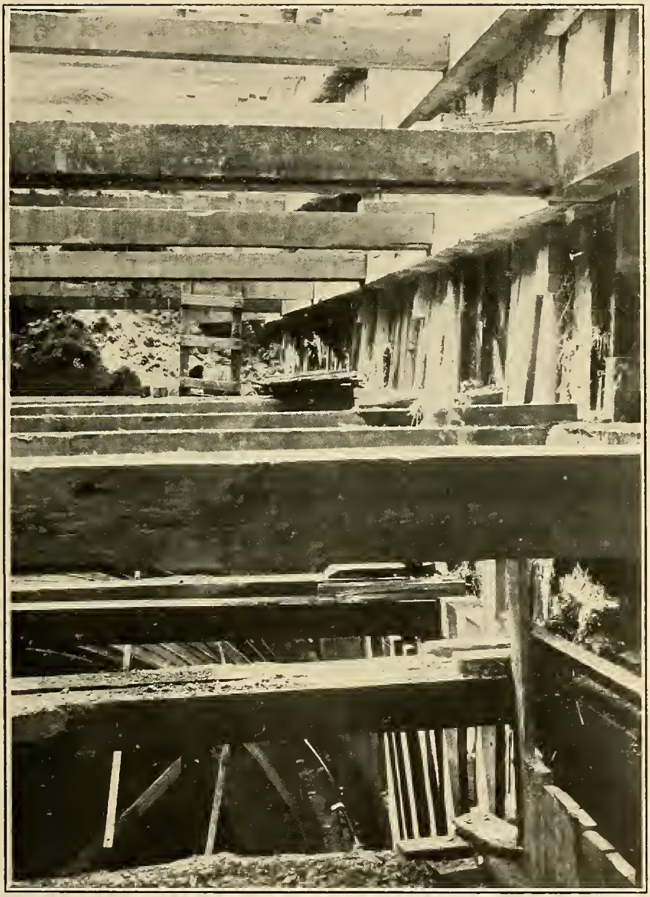


FIG. 16. 13′ 6″ SEWER, 40 FEET DEEP.

the anchor bars are either bolted temporarily to longitudinal 2 inch x 4 inch scantlings or to the longitudinal side bars which are supported at the proper line and grade.

The brick lining of the sewer, at the side and above the lower ends of the anchor bars, is now laid, and the concrete backing is rammed in place as the brickwork progresses, or, as preferred by some contractors, the concrete backing is built a day in advance of the brickwork, behind special forms. As soon as the side walls are built up to the springing line and have had about twenty-four hours' time to harden, the centering for the arches is erected. This centering is now covered with a layer of building paper, treated with oil or paraffine. The main arch bars are then coupled to the upper ends of the projecting anchor bars, and the longitudinal bars, provided for by the plan, are bolted or wired in place as the case may be. Portland cement concrete, made quite soft so as to require but little ramming, is deposited so as to fill the entire space between the centering and the side of the ditch, or against the plank sheeting, care being taken, however, to keep a thick layer of mortar immediately against the paper lining. The arch structure is thus carried up against the sheeting at the sides, for a distance of 15 inches above the springing line. At this point a plank is braced against the side of the ditch in such manner as to form the extrados of the arch, tangent to the curved upper portion. The remainder of the arch work is carried on and completed without the use of any exterior forms. A half-inch layer of Portland cement mortar is then applied to the entire extrados, and the mortar is allowed to take its initial set before back filling is begun. Back filling is deposited at the sides, care being taken not to injure the freshly built arch, and no dumping from the cable buckets is allowed upon the arch until the back filling has been deposited for a thickness of two or three feet over the back. Figs. 12, 13 and 14 are typical views of different parts of the sewer during construction.

Since the back filling begins while the concrete of the arch is still soft, or before it has gained any considerable strength, it is absolutely necessary to have good centering in this kind of work. The need of hard wood wedges, and of having the braces or legs which carry the arch ribs supported, spiked, or bolted together so as to absolutely prevent settlement or spreading, is of the greatest importance. A failure of some of the contractor's foremen to attend to these matters, has caused damage to certain arches, but in no case, where these details were properly attended to, has the least trouble occurred. The arches as completed have shown themselves to be stronger than could be anticipated were they built entirely of brick

masonry. The total deflection vertically of the 13-foot 6-inch sewers, built in wet trenches forty feet or more in depth, does not exceed $\frac{1}{2}$ inch, and the increase in horizontal width of the sewer does not exceed $\frac{3}{4}$ inch. These deformations are not more than half of what I have frequently observed in brick sewers having less diameter.

With one exception the plan of steel work used on the other sections is the same as that employed upon the first Beers & Doolittle contract. The steel skeleton for the Clement's contract on Gilbert Street, between Shipherd Avenue and the Lake Shore boulevard, consists of round rods instead of flat bars. This section is a very fine piece of workmanship, but on the whole I am inclined to believe that flat bars are preferable to the round ones, as they can be held more rigidly in place while being imbedded, and they also present, for a given sectional area, a greater surface of contact between the steel and the concrete. Fig. 15 is a view of a portion of this work. On this contract the excavation was made with a Vulcan steam shovel to a depth of about 18 feet, and the bottom portion of the excavation was removed with derrick and buckets.

The most difficult portion of the work is on those contracts lying along and upon the railway property. For a distance of over a mile the excavation is upwards of 30 feet deep and for a considerable distance more than 40 feet. The railway company refused to allow the sewer to be constructed by the use of ordinary methods of sheeting and bracing. As a result, the city was forced to make supplemental contracts for the use of heavy sheet piling driven along the margins of the trench before the excavation was begun. Wakefield sheet piling, made up of three thicknesses of 3 inch by 12 inch planking, bolted together in lengths of 28 feet, is driven by steam hammer with the aid of a water jet. This adds greatly to the cost of the sewer, as it was necessary to pay the contractor at the rate of $45 per 1000 feet B. M. for this sheeting. The additional precautions, required on account of the main passenger tracks of a railway only 15 feet distant, make such special precautions necessary throughout the entire work, and it would have been better, as already mentioned, if an independent right of way had been purchased, farther away from the railway track.

The work of Messrs. J. Connelly & Son under these trying conditions has been very commendable, but the progress has necessarily been slow and tedious, the monthly progress being only from 75 to 125 feet. This slow progress is also accounted for largely by the enormous quantities of earth which must be handled by the cableway, and the further fact that all the cross bracing timbers must be placed by the use of the cable, and that all of the bricks required for

the invert work must be lowered in the cable buckets. The rate of progress is therefore practically limited by the capacity of the cable machinery. The rate at which the arches can be constructed is much greater, varying from 12 feet to 36 feet daily, depending upon how much invert and side wall can be prepared. Fig. 16 is a view of this work, taken from about half way down the trench.

On account of the slow progress made by the open cut method, and to the fear of damage to some brick buildings which stand within 2 or 3 feet of the trench on the north side, the contractors negotiated with Dennon & Son to sub-let about 1000 feet of the work and to construct it in tunnel.

With the city's approval an agreement was entered into under which a full 4-ring brick sewer is to be substituted for the concrete and steel section, the work to be done under air pressure. Without going into details, I could not give my approval to this change in plan, as I feared it was an unsafe section and one which would involve the city in greater cost for the sewer, but the sub-contractors have begun work upon the tunnel, operating from a shaft located about 100 feet east of Doan Street.

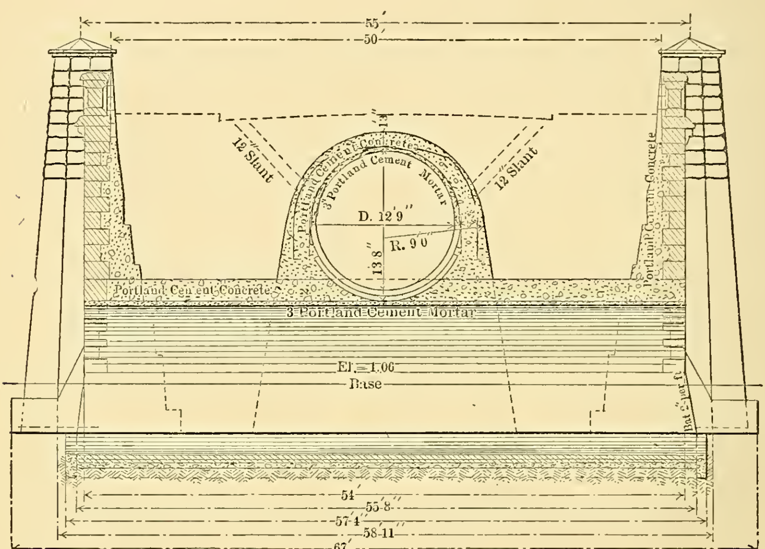
On account of the increased cost of building a sewer upon the railway land, a right of way has been acquired for the Clement's contract, extending west from Lewis Street to Bratenahl Road, and it is hoped that this portion of the work can be completed without the use of the expensive sheet piling. The change, however, was not made until about 200 feet of the sheet piling had been driven along the old location, which piling, of course, will have to be abandoned. The work of constructing the sewer, on the revised location on the north side of the railway and across Doan brook valley, is practically completed. The remainder of the contract will probably be nearly finished during the coming season.

The section extending east from Doan Street, which was awarded to Christian Burkhart, was afterward sub-let to Messrs. John Wagner & Son, who are also the contractors for the continuation of the sewer east to Eddy Road. During the past season their forces have been occupied on a section immediately west of Eddy Road, so that the Burkhardt section, although under contract for about two years, has not as yet been actually begun.

Throughout the entire season work has progressed upon the section between Eddy Road and Coit Avenue, about 600 feet of sewer having been completed. It is thus readily seen that it will be from one to two years yet before the contracts will be completed.

The terminal portion of the work in Lake Erie has not as yet

been awarded. Considerable time and study were necessary in order to determine what would be the proper method of carrying the sewage into the lake, as it requires building a sewer a distance of from 3000 to 4000 feet from shore, and making a discharge near the bottom in about 40 feet of water. The recent disasters upon the waterworks tunnel, and the further fact that test wells in the bed of the lake along the proposed route developed large quantities of marsh gas, indicated that it would be too dangerous an undertaking to build the outlet in tunnel. The cost of building a structure to this distance from shore and supporting it upon piling and break-



Section at Station 207+ 17.5

FIG. 17A. DOAN VALLEY CROSSING.

water protection, on estimate, was found to be too great. It has therefore been practically decided to lay submerged pipes in the bottom of the lake.

It is possible to dredge channels in the bed of the lake and to imbed pipes in the bottoms of these trenches. After the sand or clay has been filled over the pipes, they will be free from any danger of disturbance from the lake currents.

The flood water level in the intercepting sewer, just before its discharge into the outlet pipes, will be about 13 feet above base, or about 15 feet above ordinary lake level. It is possible, however, that, at some future time, owing to Government regulation works in the Niagara River, the water level of Lake Erie will raise the level

to base. The hydraulic grade for the outlet pipes is therefore determined by the difference of level of water in the sewer and the lake level at base. It was found on calculation that the desired capacity could be obtained by the use of one 8-foot outlet pipe and one 4-foot pipe. The 4-foot pipe would be sufficient to carry the ordinary sewage flow for some years to come, and the 8-foot pipe would be reserved for flood water discharge. Several smaller pipes could be used in place of one 8-foot pipe, but the cost would be increased and no adequate advantage gained. If it should be deemed desirable to distribute the points of discharge, branches of varying length could be made from the 8-foot pipe at a less cost than would be incurred by the use of several smaller pipes for the whole distance. By the use of one small pipe for sewage, and one large pipe for the maximum flow under storm conditions, velocities of from 10 to 13 feet per second can be obtained in the pipes, which would probably prevent the deposit of sediment or would clear the pipes of any sediment which might accumulate during dry weather conditions.

The selection of the material for these pipes is important. For the 4-foot pipe there is hardly a doubt that cast iron, all things considered, will be most suitable. But for the 8-foot pipe, the cost can be reduced by the use of wooden stave pipe. It would be difficult to prevent a pipe, made entirely of wood, from floating. By making the lower quadrant of cast iron, however, and the upper three quadrants of wooden staves, with the whole pipe properly banded with steel rods, great strength and durability could be obtained, and a considerable saving in cost effected. Such a pipe would sink of its own weight, and the lower part of the pipe, being made of cast iron, would resist the wear caused by the sediment in the flow.

It is the intention to build, at the end of the 13-foot 6-inch intercepting sewer on the margin of the lake, sedimentation and regulation tanks, so that the heavier sediment will be deposited, and thus prevented from entering the outlet pipes, and, also, for the purpose of screening off any floating rubbish. While considerable study has been given to both the matter of the sedimentation tanks and to the outlet pipes, and several different plans have been prepared, detailed plans have not yet been fully determined upon, nor any contracts let.

In the spring of 1903, a contract was awarded to the W. J. Gawne Co. for constructing the section of the main intercepting sewer immediately east of the Cuyahoga River, in Lake Street from Water Street to Muirson Street. The diameters of this sewer are 8 feet and 8 feet 3 inches, and the grade line is about 45 to 50 feet below the street surface. Borings indicated that the tunnel would be in fairly good clay, but was overlaid by beds of water-bearing sand.

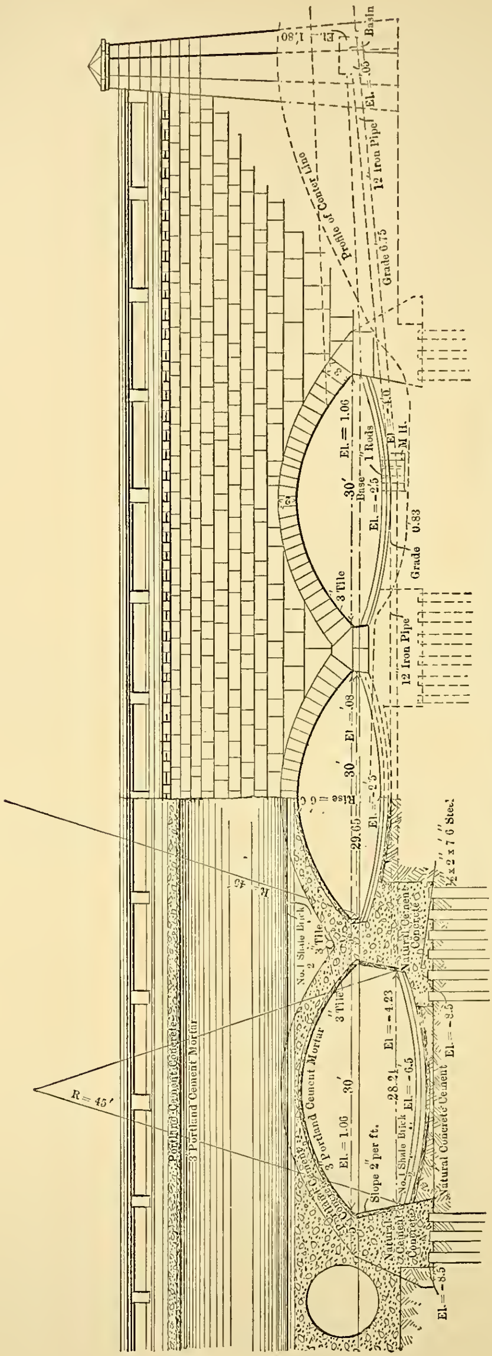


FIG. 17B. DOAN VALLEY CROSSING OF MAIN INTERCEPTOR.

Plans called for building the sewer under compressed air. At each street intersection, shafts were planned, which were later to be used as permanent manholes. According to the plan, the manhole shafts were to be braced with wooden sheeting and timbers, and then lined with 12 inches of brick masonry. Instead of the timber shaft,

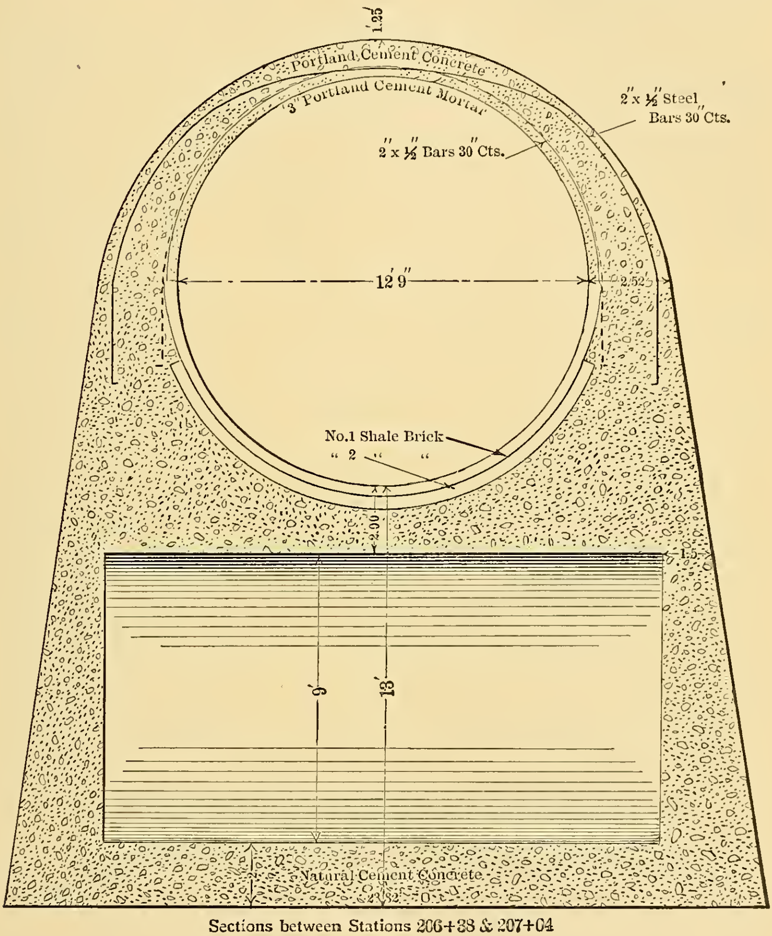


FIG. 17C. DOAN VALLEY CROSSING.

however, the contractor was allowed to use a circular steel cylinder 10 feet in diameter, which was sunk as the excavation progressed, and which was later lined with three courses of brick masonry.

The tunnel was designed circular, with three full rings of shale brick laid in Portland cement mortar. Bids were first received May 29, 1902, and awarded to John Wagner & Son, they being the lowest

bidder at $135,750. Subsequently, however, they claimed that they had made an error in calculating the cost of the manhole shafts, and induced the city to release them from their obligation. On the second letting, July 10, 1902, the work was awarded, as mentioned, to the Gawne Co. for $191,100. The work was begun about October 1, 1902, and completed about September 1, 1903.

Credit is due to the contractors for the vigorous and successful manner in which the work was carried through. They installed boilers, compressors, electric lights, and engine capacity of about double that required by the specifications. They were thus fully insured against the delays which so frequently happen in such work. The working shaft was placed near the east line of Wood Street, about the middle of the contract, and the work was driven in both directions from this shaft until it was completed. All of that part lying between Wood Street and Muirson Street was driven under air pressure of about 10 pounds per square inch, but, although they had the air-lock on hand, it was found not to be necessary for the part west of Wood Street. In each heading, a daily progress of about 16 feet was made, and as high as 18 feet was not at all uncommon.

A small 5-foot tunnel contract was let February 26, 1903, to the Ohio Contracting Company, for a temporary outlet from the main intercepting sewer, extending from Lake Street to Lake Erie, and discharging northerly on Marquette Street. This tunnel connected with the outlet portion of the Marquette main sewer. The purpose of this tunnel is, first, to afford drainage during construction for the portion of the intercepting sewer between Muirson Street and Marquette Street, and, second, to provide a temporary or emergency discharge at any subsequent time from the intercepting sewer. The work was completed during the summer of 1903 at a cost of about $10,000. No special difficulties were encountered, and no special interest pertains to the work.

The Doan valley branch intercepting sewer, as already mentioned, extends up Doan brook valley from the junction with the main interceptor a distance of nearly 4 miles to Cedar Avenue.

The sewer was located in the winter of 1900 and 1901, and bids were received in the summer of 1901, aggregating about $165,000 for the entire work. As the location had been made along the eastern bluff line of Doan valley, and for a large part of the distance in the Rockefeller parkway, objection was made to the location on the ground that the construction of the sewer would disfigure the park. It was the opinion of the Engineering Department that the damage to the park would be insignificant in comparison with the saving of

cost which could be effected by using this location. After an investigation, however, the Mayor decided against the portion of the location north of where Doan brook crosses Doan Street, and ordered a new location higher up on the bluff line to the east. This delayed the construction of the sewer one year, so that the contracts for the second location were not received until 1902, and, on account of the increased depth of the sewer and the increased cost of labor and materials required, the total cost of the Doan valley intercepting sewer was increased over $100,000. The upper section, extending from where Doan brook crosses Doan Street, however, was awarded on the original bid and location to the Clements Bros. Construction Co., but the location was almost entirely changed after the contract was awarded and the work begun. Settlements, according to this new location, have not been made with the contractor.

For the portion of the work down stream from where Doan brook crosses Doan Street, the work was awarded in three sections, the division points being at Superior Street and St. Clair Street. The portion north of St. Clair Street is under contract to the Beers & Doolittle Co. for $22,198.05, but is not yet constructed. The portion between Superior and St. Clair Streets was let to J. Connelly & Son, for about $100,000, and is nearly completed. The section extending from Superior Street up to Doan Street where Doan brook crosses, was let to J. Reaugh & Son, for about $50,000, and is completed with the exception of about 2160 feet in Doan Street extending north from Doan brook. The Doan valley sewer is of No. 4* size at the upper end, increasing to No. 8* where it joins the new interceptor. It is designed to carry a volume of mixed sewage and storm flow equal to 7 times the maximum sewage flow from the territory; and storm overflows connecting with Doan brook are therefore built on all connecting sewers. No especial interest attaches to the work, beyond the fact that a considerable portion of it is deep and a large amount of quicksand and water was encountered. The Reaugh Construction Co. built a large part of their work in tunnel, but the sand at the heading frequently caved in, so that open excavation had to be resorted to. The work will be completed down as far as St. Clair Street early the coming season, and it is the intention to build a temporary pumping plant at St. Clair Street, and pump the ordinary sewage flow westward into the end of the St. Clair Street sewer, and so prevent the discharge of connecting sewers from flowing into and polluting Doan brook.

The following general statements in regard to the intercepting sewer may be made:

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* No. 4 Cleveland egg-shaped sewer is 2.54′ x 3.23′, and the No. 8 sewer, 4.04′ x 5.12′.

The portion of the main sewer along the lake front, which is not under contract as yet, is that portion extending from Gordon Avenue, on the west side, easterly across the Cuyahoga River valley to the intersection of Water and Lake Streets; the portion from Muirson Street to Ansel Avenue and the pipe line system at the outlet into Lake Erie. None of the branches enumerated has been contracted for, with the exception of that in Doan valley, as already described. The aggregate cost of the portion of the intercepting sewer already built and under contract, will be about $2,650,000, and, for the portions of the high level system not as yet under contract, including the branches enumerated, about $2,800,000. In spite of the fact that the Cleveland sewer system has been the result of local growth and requirements, the intercepting sewers, when completed, in connection with the improved water supply, will, I believe, give the city a satisfactory solution of the problem of final disposition of its sewage, and the elimination of pollution from its water supply and water front.

VITAL STATISTICS OF ST. LOUIS SINCE 1840.

By Robert Moore, Member of the Engineers' Club of St. Louis.

[Read before the Club, January 6, 1904.*]

In the history of a city few things are more significant of the conditions of life at any time than is the death rate at that time; and in the fluctuations of the mortality curve, based upon a series of such facts, is found the best index of the success or failure of the city's inhabitants in the primary and universal struggle for existence.

But for our own city no such curve has yet been constructed; and, as the data necessary for its construction are much scattered and comparatively inaccessible, it has seemed to the writer worth while to collect and arrange them and to call attention to a few of the facts which they disclose, some of which are of special interest to the engineer.

AUTHORITIES.

The authorities for the number of deaths given in the tables presented herewith are as follows:

1. For the period from 1841 to 1854, inclusive, the total number of deaths was taken from a document found on pages 311-322 of a "Report on the Diseases of Missouri and Iowa," presented in 1855 to the American Medical Association by a committee of which Dr. Thos. Reyburn was chairman. The document in question is a short report, with tables and diagrams on "The Meteorological Causes of Climatic Diseases in St. Louis," by Dr. George Engleman, first President of the St. Louis Academy of Science and well known for his contributions to botany and local meteorology.

2. For the year 1867, all the data are from the "First Annual Report of the Board of Health of St. Louis," which was organized under a statute approved March 11th of that year, and of which Dr. John T. Hodgen was President.

3. All other data are from the annual and monthly reports of the St. Louis Health Department, organized in 1877 under the charter of the preceding year. For the years prior to 1877, the figures contained in these reports are compilations and are not as much in detail or quite as trustworthy as are those for subsequent years. For the years prior to 1867, details are greatly lacking, all that is given being the total number of deaths for each year and those due to a few special causes.

* Manuscript received June 3, 1904.—Secretary, Ass'n of Eng. Socs.

POPULATION: METHODS OF INTERPOLATION.

These authorities were drawn upon for the number of deaths and for nothing more. But in order to compute the deaths per thousand it is necessary to know, or from known facts to estimate, the population for each year. With, however, the single exception of the year 1866, when a census was taken by the city, there has been an actual enumeration but once in 10 years. It therefore becomes necessary to find the figures for the intervening years by some method of interpolation.

The first way of doing this is by the graphic method. By this method the figures for the census years are plotted as points on a diagram, years being counted on the horizontal axis and population on the vertical axis. The points thus established are then joined by curved lines which shall fit them as nearly as possible. The population for the intercensal years is given by the ordinates of the points where the joining line crosses the lines for those years. This method is based upon the assumption that the increase of population is a continuous flow, and that the values for each year, if plotted on a diagram, will lie in a curve, with no violent breaks. When used for interpolation, the degree of accuracy attained by this method depends upon the care used in fitting a curve to the fixed points and upon the scale of the drawing.

A second method is by computation, and may be called the compound interest method. This method assumes that the annual increase between two enumerations is by a percentage of the last value, and that for the given interval this percentage is constant from year to year. This makes the interpolation between two enumerations a problem in compound interest, and the values found, if plotted, will lie on a curved and not on a straight line.

A third method is the so-called "arithmetical method," adopted by the United States Census Bureau. It is based upon the assumption that the increment for each year between two successive enumerations is not a constant percentage, but a constant quantity, to wit: one-tenth of the decennial increase. This method makes the work of interpolation between two enumerations a matter of simple addition of a constant increment, and the values thus found, if plotted, will lie in a straight and not in a curved line. The diagram for several census periods would, therefore, be a polygon with angles at each census year. This means that at each census year, and at no others, the yearly increment of population changes, a proposition for which there is no foundation either in reason or in fact.

The same objection holds in regard to the compound interest method, in which the percentage of annual increase changes at the census years and at no others. In fact, however, the time of taking the census and the rate of increase of population have no necessary relation of any kind to each other. In the normal growth of a city the percentage of increase, as well as the actual increment, changes slightly from year to year with no great or abrupt changes at any time.

But this assumption is the basis of the graphic method, which is therefore the method most in accordance with the underlying

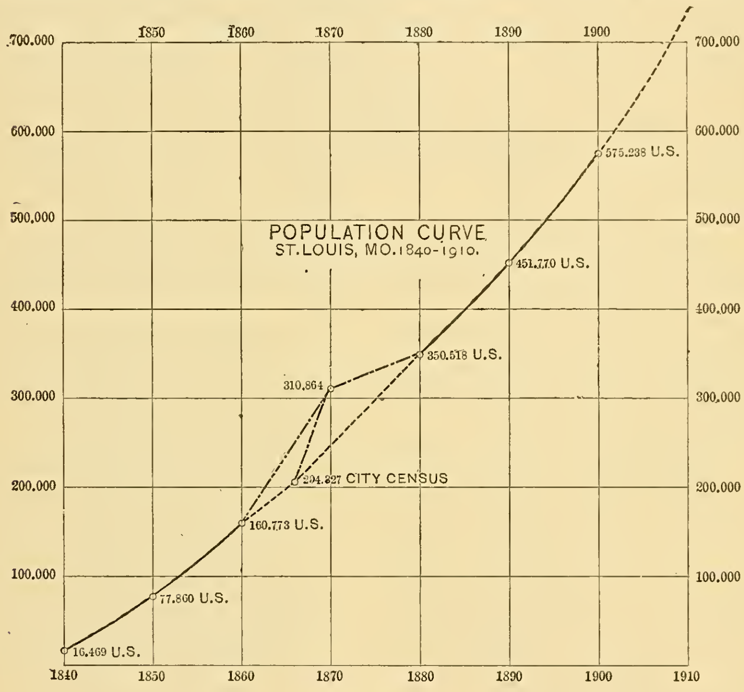


DIAGRAM 1.

fact of a continuous and slowly changing process. It is true that the values thus given are never quite exact, but may always be somewhat in error. But the percentage of such error is probably never greater than that of an enumeration, which in a large city can never be exactly correct, and the apparent exactness given by other methods is delusive. On the other hand, the graphic method, as we shall presently see, has the signal advantage of making the detection of any large errors easy and certain.

In this investigation, therefore, the writer has adopted the graphic method and in computing death rates has, for the intercen-

sal years, used population values which were scaled from a carefully drawn diagram. Such a diagram for the population of St. Louis from 1840 to the present time is submitted herewith (Diagram 1).

In looking at this diagram a conspicuous feature is the fact that the point representing the census figures of 1870 does not fit into the series, but that its inclusion in the curve makes a bad and very improbable break. This is particularly true if the figures of the census of 1866, taken by the city, be also included. On the other hand, if the census of 1870 be excluded the curve becomes fairly smooth. The only exception is a slight downward bend caused by the census of 1866. If, however, we bear in mind the depressing effects of the Civil War and the cholera epidemic of 1866, this drop in the curve is fully explained. In like manner the steeper slope between 1866 and 1880 is accounted for by the renewed prosperity following the war and also by the extension of the city limits in 1870 and again in 1876.

This lack of congruity in the census of 1870, as shown by the diagram, brings out clearly the fact that this census is unreliable and worthless; and from direct testimony there is little room for doubt that it was padded and fraudulent. So clear was this that in 1880 the Health Department, which before then had been seriously misled, was forced to discard the census of 1870 and to reduce the population figures for this year by more than 60,000.

During the 20 years from 1880 to 1900 there were no changes in the city limits, the city's growth was normal and there were no efforts to inflate the census figures. As a consequence the curve for this period is smooth and regular, and beyond doubt expresses very closely the facts of the city's growth during these years. And in the absence of an actual enumeration, the prolongation of this curve, shown in the diagram, is the best available index to the present population.

RESULTS.

Applying the figures for the population thus obtained to those giving the number of deaths, already referred to, the deaths per 1000 have been computed for each year from 1841 to 1903, inclusive, a period of 63 years. The results are set forth in Tables 1 and 2 and the diagrams which accompany them.

It may be remarked in passing that the record thus shown is perhaps as long as can be shown for any American city. Even for London, exact records do not go farther back than 1838. The first

DIAGRAM 2. DEATH RATES PER 1000 OF POPULATION, 1840-1903.

of the series of annual reports of the Registrar General of England was published in 1839.

Referring to Diagram 2, which shows the death rates from all causes, the first thing to strike the eye is the very high death rate which prevailed during the first 3 decades, from 1841 to 1870,

inclusive. During the first 2 decades the lowest rate reached was 26.07 per 1000 for the single year 1842, the rest ranging from 28.93, in 1856, up to maximum of 120.3, in 1849. In the third decade, 1861-70, there were but 3 years below 25, the other 7 years ranging from 27.11 up to 44.54.*

The violent fluctuations from year to year are also very noticeable. We find, for example, differences between succeeding years of 12.67, 13.81, 14.99, 21.20, 26.90, and in one case as much as 77.93

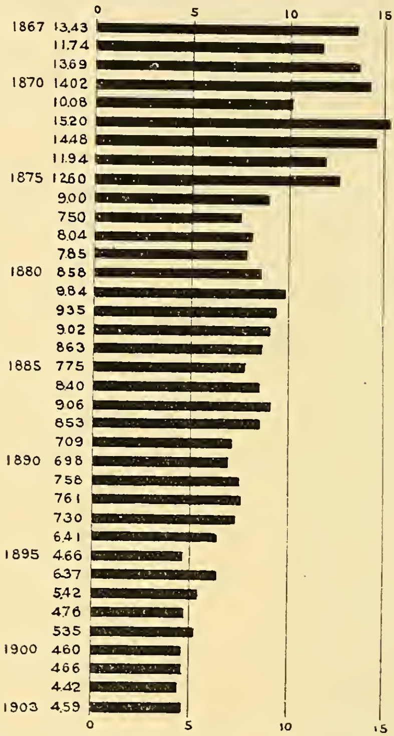


Diagram 3. Death Rates under 5 Years, 1867-1903.

per 1000. All of these wide fluctuations, with the possible exception of 26.90 between 1842 and 1843, were due to epidemics of cholera. There were also epidemics of cholera during the previous decade, 1831-40, though the exact figures cannot be given; so that for 40 years cholera was almost as great a scourge in St.

* There is little doubt that the mortality from cholera during the first two decades was materially increased by the deaths of immigrants who had come to the city on their way to points further west; but as the number of such deaths cannot now be told there is nothing to do but to leave the figures as they stand.

Louis as in Calcutta. In this, however, St. Louis was not alone. The cholera diagram for London during this period has a striking resemblance to that of St. Louis. There, as here, there was a sharp epidemic in 1849, and again in 1854 and in 1866; and it is more than probable that the diagrams for other American cities would show a like resemblance. Prior to 1870 cholera was a source of terror to the whole civilized world, and when it appeared in St. Louis it could always be traced back to Europe; but though not

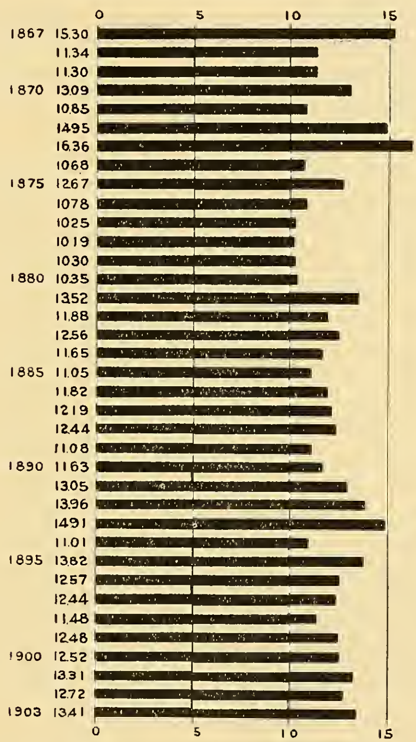


Diagram 4. Death Rates, 5 Years and over, per 1000 of Population, 1867-1903.

indigenous, it never failed, during these first 3 decades at least, to find here a most prolific soil.

During the last 3 decades from 1871 to 1900, inclusive, the improvement in the health conditions of St. Louis is very marked. Both the maximum and the minimum mortality rates are much lower than during the preceding period. The 3 worst years were 1872, 1873 and 1875, when the death rates were 30.15, 30.84 and 25.27 per 1000 respectively. These high rates were mainly due to

smallpox, from which cause there were, in 1872, nearly 1600 deaths, or 5.96 per 1000, an intensity which reminds us of the days before Dr. Jenner. But here, again, we find like conditions to have prevailed elsewhere. In 1871 and 1872 smallpox was epidemic in London. In 1872 and 1873 it was epidemic also in Boston, though it was not as severe as in St. Louis. In addition to smallpox there was, in 1875, an epidemic of scarlet fever, which caused 508 deaths, or 1.71 per 1000, the largest rate on record from this cause in the history of the city.

Since 1875 the highest rate reached was 23.36, in the year 1881; that is to say, the maximum rate for the last 28 years is barely more than the minimum rate for the 30 years 1841-1870. In 1898 was the lowest rate for the whole period of 63 years, to wit, 16.24 per 1000.

The rates for each of the 6 complete decades and for the 3 years, 1901-03, of the seventh decade are shown by the following table. In this table are also given the mean duration of life corresponding to each rate * and the change therein for each period.

Period.	Death Rate per 1000.	Mean Duration of Life.	Change from Last Period.
1841-1850	55.18	18.12	
1851-1860	38.62	25.89	7.77
1861-1870	30.13	33.19	7.30
1871-1880	21.94	45.58	12.37
1881-1890	20.43	48.94	3.36
1891-1900	18.64	53.65	4.71
1901-1903	17.71	56.48	2.83

From this it appears that the death rate, which for the first decade was 55.18, has declined until for the last 3 years it has been 17.71 per 1000, or less than one-third of what it was at the outset; or, to state the same facts in other words, the expectation of life of the child born in the years 1841-1850 was only 18.12 years; for the child born in 1902-03 it was 56.48 years, or over 3 times as long. The total increase in the mean duration of life was 38.36 years, a record of gain which it is difficult to equal.

COMPARISON WITH OTHER CITIES.

To show how the present death rate in St. Louis compares with those of other American cities, a table giving the population and death rate for 14 such cities, compiled from the census of 1890, is subjoined.

* The rates for the several periods here given are the quotients obtained by dividing the mean yearly deaths for each period by the mean population for the same period.

City.	Population.	Death Rate.
New York	3,437,202	20.4
Chicago	1,698,575	16.2
Philadelphia	1,293.697	21.2
Boston	560,892	20.1
Baltimore	508,957	21.0
Cleveland	381,768	17.1
Buffalo	352,387	14.8
San Francisco	342,782	20.5
Cincinnati	325,902	19.1
Pittsburg	321,616	20.1
New Orleans	284,104	28.9
Detroit	285,704	17.1
Milwaukee	285,315	15.7
Washington	278,718	31.1

The average rate for 1900 in these 14 cities was 19.63, or 1.93 greater than the St. Louis rate for the years 1901-03. The only cities showing a less rate than ours are Chicago, Cleveland, Buffalo, Detroit and Milwaukee, in which the average rate for 1900 was 16.22, or 1.48 less than our own. In regard to these cities, however, it is worthy of note that the percentage of negroes, among whom the death rate is always much greater than among the whites, is very small, namely 1.12 per cent. as compared with 6.2 per cent. in St. Louis. Besides which a close scrutiny of the facts might show that the figures of population in these cities are incorrect; for, as we have already seen in our own history for 1870, even a census report may be heavily padded, of which there is no surer sign than an exceptionally low death rate. For example, when we find, as we do in the census figures for 1900, 3 cities, one of them in Missouri, in which the death rates indicate a mean duration of life of 103, 105 and 110 years respectively, we can be very sure that the figures of population need to be revised.

CONTROL OF EPIDEMICS.

Coming now to the causes of this very great lowering of the death rate and the consequent increase in the mean duration of life, we find, as a general statement, that it is due to a better knowledge of the causes and cure of disease and the methods of its prevention, and to a better observance of the laws of health which this knowledge has disclosed.

This is well illustrated in the case of cholera, which, as we have seen, was for 30 years in St. Louis a frightful scourge. But at that time its cause and the methods of its propagation were unknown. When, therefore, the pestilence appeared the people knew not what to do. In their bewilderment the city authorities

appointed days of fasting and prayer and burned tar barrels in the streets, meantime doing nothing really effective to prevent the disease from spreading. Were it to appear now, something extremely

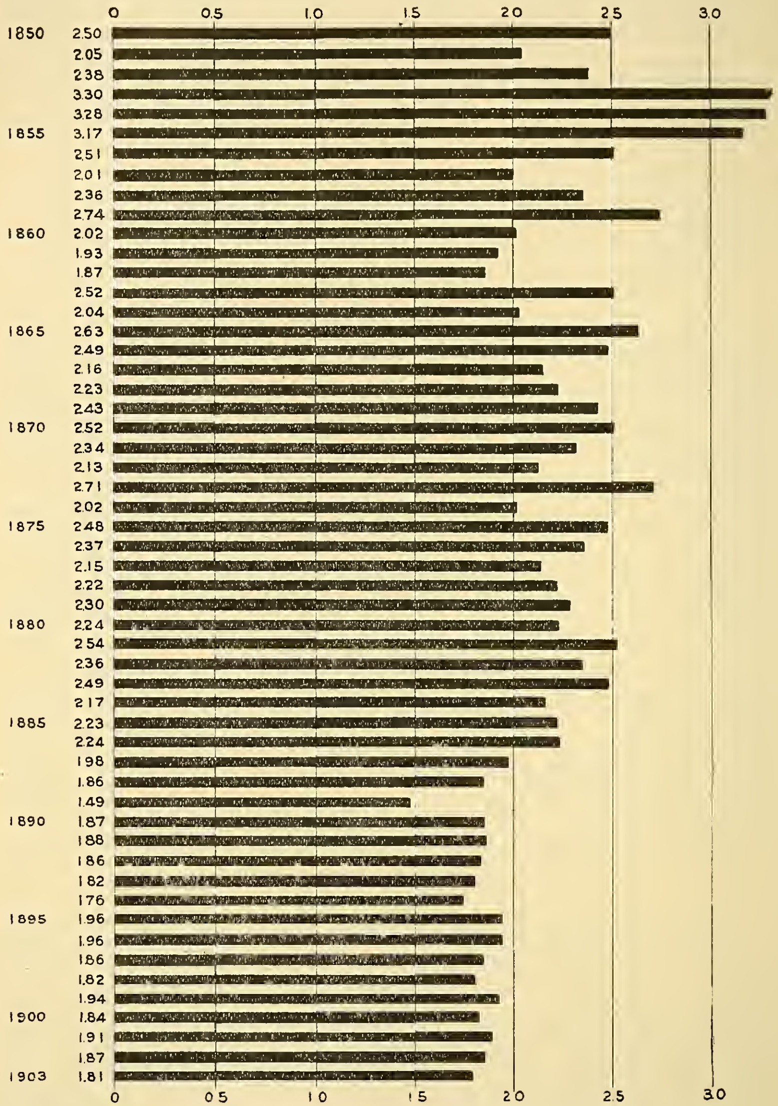


Diagram 5. Consumption Death Rates per 1000 of Population, 1850-1903.

improbable, the cases would be promptly isolated, the excreta disinfected, and a general purification of drinking water by filtration and by boiling inaugurated; for by such measures, as we now

know, the propagation of the disease is made impossible. In fact cholera is not likely, hereafter, ever to become epidemic in any large European or American city. Much the same may be said of smallpox, of yellow fever and of the plague, for each of which the means of prevention are now well known.

REDUCTION OF THE INFANT DEATH RATE.

Next in importance to the control of epidemics as a factor in increasing the mean duration of life has been the very marked

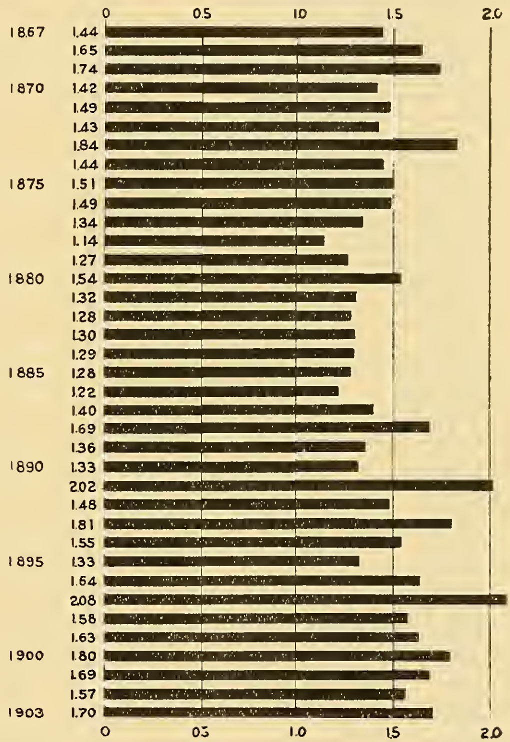


DIAGRAM 6. PNEUMONIA DEATH RATES PER 1000 OF POPULATION, 1867-1903.

decrease in the deaths of children under 5 years, which, for the 37 years from 1867 to 1903, inclusive, is shown in Table 2 and Diagram 3, herewith submitted. As a rule, with almost no exceptions, this class embraces a larger number of individuals than is found in any other class embracing an equal number of years. Potentially, therefore, no class of the population is more important. In the last two censuses the proportions of the population embraced in this class in the whole United States have been, for 1890, 12.2

per cent. and for 1900, 12.1 per cent. In St. Louis they have been, for 1890, 9.96 per cent. and for 1900, 9.91 per cent. For round numbers, therefore, we may say that the proportion of the popula-

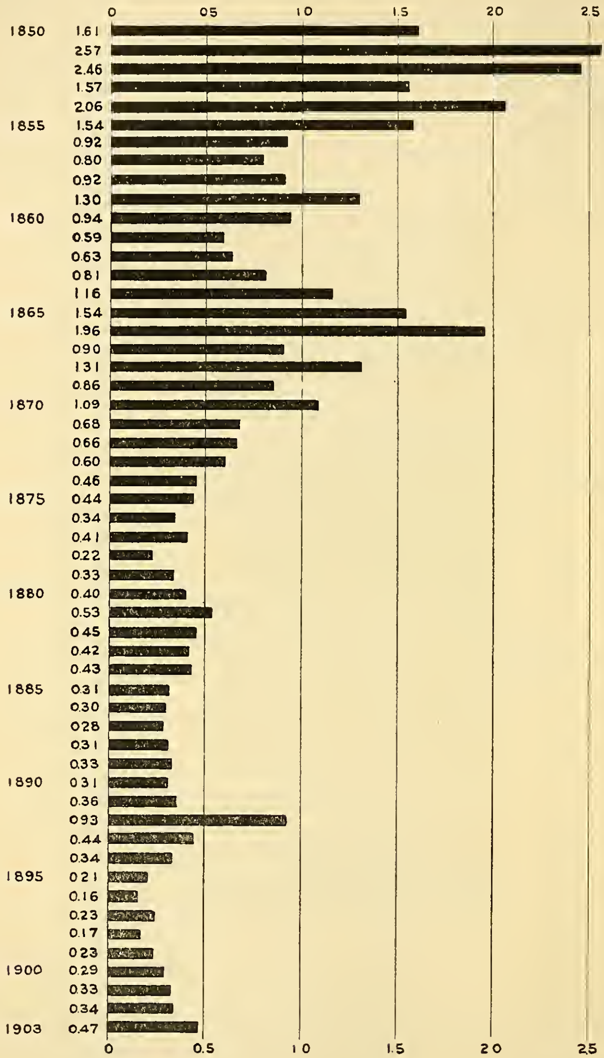


Diagram 7. Typhoid Fever Death Rates per 1000 of Population, 1850-1903.

tion under 5 years of age in St. Louis is 10 per cent. Being also the feeblest element of the population they are the most easily affected by morbific influences, a liability which inevitably results in a higher death rate than is found in any other class.

Table 2 shows that during the 4 years from 1867-1870 the deaths of children from 1 to 4 years of age amounted to 13.25 per 1000 of the total population, which, bearing in mind that this class numbers one-tenth only of the whole, means a rate of 132.5 per 1000 of those belonging to this class. For the years 1872 and 1873 the rates per 1000 of those belonging to this class were 152 and 148.8 respectively, or more than 1 in every 7. Since 1873 this rate has rapidly decreased until for the 3 years

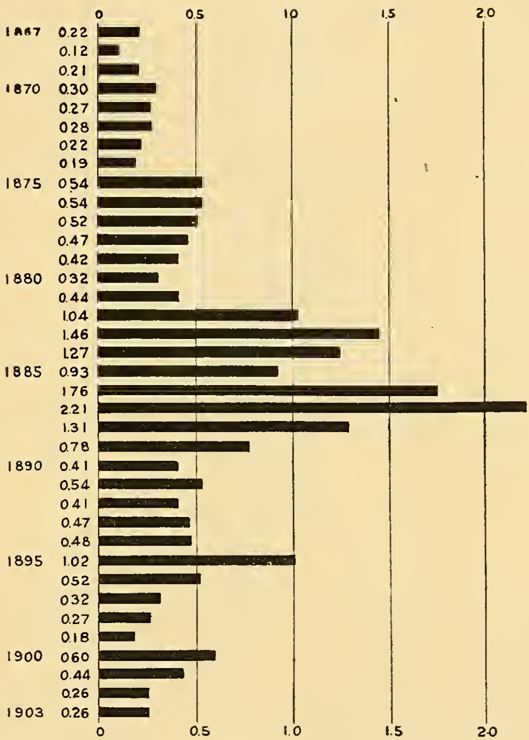


DIAGRAM 8. DIPHTHERIA DEATH RATES PER 1000 OF POPULATION, 1867-1903.

1901-03 it was 45.6 per 1000, still a very high rate, but less than one-third of what it was only 30 years before.

Meantime the changes in the death rate of the remaining nine-tenths of the population, embracing all those of 5 years of age and over, as shown in Diagram 4, have been comparatively small. This fact is brought out in the following table, which gives the deaths and the death rates in St. Louis from 1867 to 1903, inclusive, first for children under 5 years, and, second, for all persons 5 years of age and over.

Period.	Sum of Population per Year.	Children under Five Years of Age. Total Deaths.	Rate per 1000 of the Class.	All Persons Five Years of Age and Over. Total Deaths.	Rate per 1000 of the Class.
1867-1870	921,400	12,209	132.48	11,709	14.12
1871-1880	3,032,918	31,319	102.32	35,071	12.85
1881-1890	4,045,670	34,059	84.19	48,601	13.35
1891-1900	5,173,438	30,703	59.35	65,719	14.11
1901-1903	1,813,000	8,261	45.01	23,838	14.61
1867-1903	14,986,426	116,551	77.77	184,938	13.71

From this table it will be seen that during the decade 1871-80 the rate per 1000 of those 5 years of age and over dropped from 14.12 to 12.85, or 1.27 per 1000. Since then, however, it has been slowly increasing, and for the 3 years 1901-03 was 14.61, which is 1.76 per 1000 greater than in 1871-80 and 0.49 greater than in 1867-70. So that since 1866, the date of the last great epidemic of cholera, the decrease in the total death rate is wholly due to the very marked decrease in the deaths of children during the first 4 years of life.

This revolutionary reduction in the infantile death rate—one of the most important events in the city's history—has been brought about, speaking broadly, by greater knowledge of the causes of disease, and, as a result of such knowledge, by better food and more skillful care. Part of it has been brought about by the better control of diphtheria since the introduction of the seropathic treatment. (See Diagram 8.)

CONSUMPTION AND PNEUMONIA.

Next after the mortality among children under 5 years as a factor in the general death rate is consumption, the course of which from 1850 to 1903 is shown in Tables 1 and 2 and on Diagram 5. Here also we note a decline from 2.56 per 1000 for the 11 years 1850-60 to 1.81 in 1903, and 1.89 for the 13 years 1891-1903. This decline is part of a general movement in all enlightened countries, which in Massachusetts has brought the death rate from this cause down from 3.99 per 1000 in the decade 1851-60 to 1.59 in 1902, a reduction of over 60 per cent. It is noteworthy that in St. Louis the most marked reduction has taken place since 1886, soon after Dr. Koch's announcement of the true cause of the disease. That by sanatoriums for the open-air treatment and by the general diffusion of knowledge as to the means of prevention the mortality from this cause can be still further lowered there can be no doubt.

Following closely consumption as a cause of death is pneumonia, the course of which in St. Louis from 1867 to 1903, inclusive, is shown in Table 2 and Diagram 6. Here, however, we find that for

the last 13 years the deaths from this cause have been increasing, so that it is now almost as serious a foe to life as consumption. In fact there have been 2 years, 1891 and 1897, when the deaths from pneumonia exceeded those from consumption. The same conditions substantially are found in Massachusetts, where, in 1900, pneumonia slightly exceeded consumption as a cause of death. Nor is the outlook for gaining the mastery over it at present very promising.

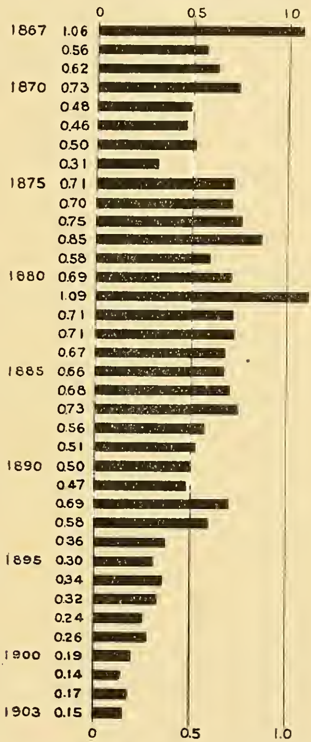


DIAGRAM 9. MALARIA DEATH RATES PER 1000 OF POPULATION, 1867-1903.

TYPHOID FEVER.

In the list of preventable diseases that of greatest interest to the engineer is typhoid fever, the history of which in St. Louis for 54 years, from 1850 to 1903, is given in Tables 1 and 2 and is shown graphically by Diagram 7.

In studying this diagram the first thing to strike the eye is the fact that taking it as a whole there has been a very great decline. From a rate of 1.42 per 1000 in the 11 years 1850-60 there is in the decade 1891-1900 a drop to a rate of 0.33, which is less than one-fourth of the former rate. A second noticeable feature is the wide

TABLE I.

POPULATION, DEATHS AND DEATH RATES, 1841 TO 1866.

Year.	Population.	Deaths. All Causes.		Cholera.		Total Except Cholera.		Consumption.		Typhoid.		Smallpox	
		Number.	Rate per 1,000.	Deaths.	Rate per 1,000.	Deaths.	Rate per 1,000.	Deaths.	Rate per 1,000.	Deaths.	Rate per 1,000.	Deaths.	Rate per 1,000.
1840	16,469												
1841	21,800	960	44.04										
1842	27,000	720	26.67										
1843	32,800	1,160	53.57										
1844	38,600	1,579	40.91										
1845	44,600	1,701	38.14										
1846	51,000	2,055	40.29										
1847	57,200	2,866	50.10										
1848	63,800	2,7C3	42.37										
1849	70,600	8,495	120.30	4,317	61.12	4,178	59.18						
1850	77,860	4,539	58.29	883	11.33	3,656	46.96	195	2.50	125	1.61	7	0.09
1851	84,800	4,388	51.75	845	9.97	3,543	41.78	174	2.05	218	2.57	7	0.08
1852	92,300	4,881	52.88	802	8.69	4,079	44.19	220	2.38	227	2.46	39	0.42
1853	100,000	3,889	38.89	10	0.10	3,879	38.79	330	3.30	157	1.57	22	0.22
1854	107,800	6,802	63.10	1,534	14.22	5,268	48.88	353	3.28	222	2.06	4	0.04
1855	116,000	5,231	45.10	534	4.61	4,697	40.49	368	3.17	179	1.54	28	0.24
1856	124,500	3,602	28.93	5	0.05	3,597	28.88	323	2.51	114	0.92	10	0.08
1857	133,100	4,065	30.54	7	0.05	4,058	30.49	268	2.01	107	0.80	159	1.19
1858	142,000	4,231	29.80	22	0.17	4,209	29.63	335	2.36	131	0.92	15	0.11
1859	151,300	4,765	31.49	13	0.08	4,752	31.41	414	2.74	197	1.30	2	0.01
1860	160,773	4,978	30.96	1	0.00	4,977	30.96	324	2.02	151	0.94	0	0.00
1861	168,200	4,170	24.79	1	0.00	4,169	24.79	324	1.93	100	0.59	2	0.01
1862	175,400	5,236	29.85	7	0.04	5,229	29.82	328	1.87	110	0.63	46	0.26
1863	182,600	5,951	32.59	7	0.04	5,944	32.55	461	2.52	147	0.81	109	0.59
1864	189,800	6,893	36.32	2	0.01	6,891	36.31	388	2.04	220	1.16	63	0.33
1865	197,000	6,157	31.25	4	0.02	6,153	31.23	518	2.63	304	1.54	114	0.58
1866	204,327	9,099	44.54	3,527	17.27	5,572	27.27	508	2.49	401	1.96	27	0.13

Year	Population.	All Causes. Total Deaths.		Cholera.		Smallpox.			Total Excl. Two	Year.
		Deaths.	Rate per 1,000	Deaths.	Rate per 1,000	Cases.	Deaths.	Rate per 1,000	No.	
1867	214,800	6,171	28.73	684	3.19	89	18	0.08	5,469	1867
1868	225,100	5,193	23.08	1		10	1		5,191	1868
1869	235,500	5,884	24.99	2		502	240	1.02	5,642	1869
1870	246,000	6,670	27.11	3			375	1.52	6,292	1870
1871	256,500	5,265	20.93	1			9	0.04	5,255	1871
1872	266,900	8,047	30.15	5	0.02	3,789	1,591	5.96	6,451	1872
1873	277,300	8,551	30.84	131	0.47		837	3.02	7,583	1873
1874	287,600	6,506	22.62				447	1.55	6,059	1874
1875	298,000	7,532	25.27				603	2.02	6,929	1875
1876	308,200	6,019	19.78				90	0.29	5,929	1876
1877	318,800	5,660	17.75			13	1		5,659	1877
1878	329,300	6,002	18.23						6,002	1878
1879	339,800	6,167	18.15						6,167	1879
1880	350,518	6,636	18.93			9			6,636	1880
1881	360,000	8,410	23.36				115	0.32	8,295	1881
1882	369,500	7,845	21.23				41	0.11	7,804	1882
1883	379,000	8,177	21.58				233	0.61	7,944	1883
1884	388,800	7,887	20.28			104	29	0.07	7,858	1884
1885	398,500	7,490	18.80			3			7,490	1885
1886	408,800	8,268	20.22						8,268	1886
1887	419,000	9,155	21.85			17	1		9,154	1887
1888	429,800	9,015	20.97			90	10	0.02	9,005	1888
1889	440,500	8,004	18.17						8,004	1889
1890	451,770	8,409	18.61			52	5	0.01	8,404	1890
1891	462,600	9,530	20.60			26	5	0.01	9,525	1891
1892	474,000	10,225	21.57						10,225	1892
1893	485,800	10,303	21.21			3	1		10,302	1893
1894	497,800	8,710	17.50			229	49	0.10	8,661	1894
1895	510,000	9,425	18.48			114	24	0.05	9,401	1895
1896	522,500	9,897	18.94			1			9,897	1896
1897	535,000	9,554	17.86			10	3	0.006	9,551	1897
1898	548,500	8,908	16.24			2	0		8,908	1898
1899	562,000	10,023	17.83			115	5	0.009	10,018	1899
1900	575,238	9,847	17.12			134	2	0.003	9,845	1900
1901	590,000	10,601	17.97			879	9	0.015	10,592	1901
1902	604,000	10,353	17.14			1,548	17	0.03	10,336	1902
1903	619,000	11,145	18.00				3	0.005	11,142	1903

TABLE 2.

POPULATION, DEATHS, AND DEATH RATES.

1867 to 1903, inclusive.

Year	Population.	All Causes. Total Deaths. Deaths.	Rate per 1,000	Cholera. Deaths	Rate per 1,000	Smallpox. Cases.	Deaths.	Rate per 1,000	Total Deaths Excluding Two Last. No.	Rate per 1,000	Under 5 years. Deaths.	Rate per 1,000	5 years and over. Deaths.	Rate per 1,000
1867	214,800	6,171	28.73	684	3.19	89	18	0.08	5,469	25.46	2,953	13.43	3,218	15.30
1868	225,100	5,193	23.08	1		10	1		5,191	23.06	2,582	11.74	2,611	11.34
1869	235,500	5,884	24.99	2		502	240	1.02	5,642	23.96	3,225	13.69	2,659	11.30
1870	246,000	6,670	27.11	3			375	1.52	6,292	25.85	3,449	14.02	3,221	13.09
1871	256,500	5,265	20.93	1			9	0.04	5,255	20.49	2,585	10.08	2,680	10.85
1872	266,900	8,047	30.15	5	0.02	3,789	1,591	5.96	6,451	24 17	4,058	15.20	3,989	14.95
1873	277,300	8,551	30.84	131	0.47		837	3.02	7,583	27.35	4,014	14.48	4,537	16.36
1874	287,600	6,506	22.62				447	1.55	6,059	21.07	3,433	11 94	3,073	10.68
1875	298,000	7,532	25.27				603	2 02	6,929	23 25	3,755	12.60	3,777	12.67
1876	308,200	6,019	19.78				90	0.29	5,929	19.24	2,840	9.00	3,179	10.78
1877	318,800	5,660	17.75			13	1		5,659	17.75	2,391	7.50	3,269	10.25
1878	329,300	6,002	18.23						6,002	18.23	2,635	8.04	3,367	10.19
1879	339,800	6,167	18.15						6,167	18.15	2,666	7.85	3,501	10.30
1880	350,518	6,636	18.93			9			6,636	18.93	2,937	8.58	3,699	10.35
1881	360,000	8,410	23.36				115	0.32	8,295	23.04	3,541	9.84	4,869	13.52
1882	369,500	7,845	21.23				41	0.11	7,804	21 12	3,454	9.35	4,391	11.88
1883	379,000	8,177	21.58				233	0.61	7,944	20.96	3,420	9.02	4,757	12.56
1884	388,800	7,887	20.28			104	29	0 07	7,858	20 22	3,357	8.63	4,530	11.65
1885	398,500	7,490	18.80			3			7,490	18.80	3.090	7.75	4,400	11.05
1886	408,800	8,268	20.22						8,268	20.22	3,434	8.40	4,834	11.82
1887	419,000	9,155	21.85			17	1		9.154	21.85	3,795	9.06	5,360	12.19
1888	429,800	9,015	20.97			90	10	0.02	9,005	20.95	3,659	8.53	5,356	12.44
1889	440,500	8,004	18.17						8,004	18.17	3.194	7.09	4,810	11.08
1890	451,770	8,409	18.61			52	5	0.01	8,404	18.60	3,115	6.98	5,294	11.63
1891	462,600	9,530	20.60			26	5	0.01	9,525	20.59	3,493	7.58	6,037	13.05
1892	474,000	10,225	21.57						10,225	21.57	3,607	7.61	6,618	13.96
1893	485,800	10,303	21.21			3	1		10,302	21.21	3,548	7.30	6,755	14.91
1894	497,800	8,710	17.50			229	49	0.10	8,661	17.40	3,192	6.41	5,518	11.01
1895	510,000	9,425	18.48			114	24	0.05	9,401	18.43	2,375	4.66	7,050	13.82
1896	522,500	9,897	18.94			1			9,897	18.94	3,326	6.37	6,571	12.57
1897	535,000	9,554	17.86			10	3	0.006	9,551	17.85	2,901	5.42	6,653	12.44
1898	548,500	8,908	16.24			2	0		8,908	16.24	2,608	4.76	6,300	11.48
1899	562,000	10.023	17.83			115	5	0.009	10,018	17.82	3,005	5.35	7,018	12.48
1900	575,238	9,847	17.12			134	2	0.003	9,845	17.12	2,648	4.60	7,199	12.52
1901	590,000	10,601	17.97			879	9	0.015	10,592	17.95	2,748	4.66	7,853	13.31
1902	604,000	10,353	17.14			1,548	17	0.03	10,336	17.11	2,671	4.42	7,682	12.72
1903	619,000	11,145	18.00				3	0.005	11,142	18.00	2,842	4.59	8,303	13.41

Year	Scarlatina. Deaths.	Rate per 1,000	Diphtheria. Deaths	Rate per 1,000	Croup. Deaths.	Rate per 1,000	Typhoid Fever. Deaths.	Rate per 1,000	Diarrheal, under 5 years. Deaths.	Rate per 1,000	Diarrheal, 5 years and over. Deaths	Rate per 1,000	Diarrhea. Total. Deaths	Rate per 1,000	Malaria. Deaths.	Rate per 1,000	Consumption. Deaths.	Rate per 1,000	Pneumonia Deaths.	Rate per 1,000	Still Births not Included in Total.	Births Reported.	Year.
1867	27	0.13	48	0.22	58	0.27	194	0.90	173	0.81	823	3.83	996	4.64	227	1.06	464	2.16	309	1.44	371		1867
1868	28	0.12	35	0.12	44	0.20	294	1.31	409	1.82	511	2 27	920	4.09	127	0.56	503	2.23	371	1.65	411		1868
1869	55	0.23	49	0.21	51	0.22	202	0.86	469	1.99	407	1.73	876	3.72	147	0.62	571	2.43	410	1.74	421		1869
1870	263	1.07	75	0.30	92	0.27	269	1.09	371	1.54	528	2.15	899	3.66	180	0.73	620	2.52	350	1.42	407		1870
1871	68	0.27	68	0.27	79	0.31	174	0.68	221	0.86	316	1 23	537	2.09	124	0.48	599	2.34	381	1.49	363		1871
1872	47	0.18	76	0.28	66	0.25	176	0.66	456	1.71	544	2.04	1,000	3.75	124	0.46	568	2.13	382	1.43	630		1872
1873	22	0.08	61	0.22	78	0.28	167	0.60	496	1.79	691	2.49	1,187	4.28	140	0.50	751	2.71	510	1.84	514		1873
1874	87	0.30	56	0.19	53	0.18	131	0.46	460	1.60	295	1.03	755	2.63	88	0.31	581	2.02	413	1.44	510		1874
1875	508	1.71	160	0.54	72	0.24	131	0.44	378	1.27	315	1.06	693	2.33	212	0.71	740	2.48	450	1.51	421		1875
1876	124	0.40	167	0.54	157	0.51	103	0.34	314	1.02	248	0.80	562	1.82	216	0.70	721	2.37	460	1.49	401		1876
1877	40	0.13	165	0.52	69	0.21	130	0.41	197	0.62	234	0.73	431	1.35	240	0.75	686	2.15	427	1.34	767		1877
1878	36	0.11	156	0.47	85	0.26	74	0.22	238	0.72	213	0.65	451	1.37	279	0.85	730	2.22	375	1.14	434	4,681	1878
1879	39	0.11	141	0.42	62	0.18	112	0.33	477	1.40	189	0.56	666	1.96	197	0.58	781	2.30	432	1.27	541	4,641	1879
1880	47	0.13	113	0.32	61	0.17	139	0.40	488	1.39	161	0.46	649	1.85	241	0.69	786	2.24	539	1.54	561	7,525	1880
1881	108	0.30	157	0.44	68	0.19	191	0.53	686	1.91	195	0.54	881	2.45	393	1.09	913	2.54	475	1.32	668	8,066	1881
1882	346	0.94	385	1.04	103	0.28	166	0.45	525	1.42	179	0.48	704	1.90	264	0.71	870	2.36	474	1.28	705	8,401	1882
1883	349	0.92	553	1.46	134	0.35	158	0.42	531	1.40	136	0.36	667	1.76	270	0.71	944	2.49	493	1.30	709	8,835	1883
1884	161	0.41	495	1.27	116	0.30	166	0.43	582	1.50	130	0.33	712	1.83	261	0.67	844	2.17	501	1.29	790	9,634	1884
1885	164	0.41	372	0.93	109	0.27	125	0.31	441	1.11	91	0.23	532	1.34	263	0.66	888	2.23	511	1.28	725	9,906	1885
1886	149	0.36	719	1.76	160	0.39	124	0.30	334	0.82	97	0.24	431	1.06	279	0.68	915	2.24	597	1.22	765	10,296	1886
1887	48	0.11	927	2.21	185	0.44	116	0.28	324	0.77	153	0.37	477	1.14	304	0.73	829	1.98	586	1.40	740	10,613	1887
1888	30	0.07	564	1.31	167	0.39	133	0.31	488	1.13	144	0.34	632	1.47	242	0.56	800	1.86	728	1.69	726	11,305	1888
1889	114	0.26	345	0.78	94	0.21	146	0.33	357	0.81	79	0.18	436	0.99	223	0.51	655	1.49	598	1.36	835	11,906	1889
1890	87	0.19	186	0.41	58	0.13	140	0.31	435	0.96	104	0.23	539	1.19	226	0.50	843	1.87	601	1.33	704	11,564	1890
1891	96	0.21	250	0.54	90	0.19	165	0.36	429	0.93	118	0.26	547	1.18	216	0.47	869	1.88	932	2.02	828	11,609	1891
1892	150	0.32	195	0.41	91	0.19	441	0.93	444	0.93	112	0.24	556	1.17	326	0.69	882	1.86	705	1.48	837	12,327	1892
1893	79	0.16	227	0.47	144	0.30	215	0.44	570	1.17	111	0 24	681	1.40	284	0.58	984	1.82	879	1.81	799	12,020	1893
1894	29	0.06	240	0.48	139	0.28	171	0.34	538	1.08	98	0.20	636	1.28	179	0.36	875	1.76	772	1.55	896	12,233	1894
1895	20	0.04	522	1.02	171	0.34	107	0.21	552	1.08	101	0.20	653	1.28	155	0.30	1,000	1.96	677	1.33	784	11,848	1895
1896	8	0.01	273	0.52	104	0.20	106	0.16	664	1.27	111	0.21	775	1.48	177	0.34	1,026	1.96	854	1.64	772	11,281	1896
1897	19	0.04	170	0.32	70	0.13	124	0.23	499	0.93	67	0.13	566	1.06	173	0.32	997	1.86	1,115	2.08	729	11,690	1897
1898	28	0.05	152	0.27	51	0.09	95	0.17	413	0.75	53	0.10	466	0.85	134	0.24	1,001	1.82	867	1.58	714	10,815	1898
1899	38	0.07	102	0.18	49	0.09	131	0.23	451	0.80	64	0.11	515	1.02	148	0.26	1,091	1.94	914	1.63	775	10,422	1899
1900	57	0.10	344	0.60	65	0.11	168	0.29	402	0.70	67	0.12	469	0.82	112	0.19	1,006	1.84	1,034	1.80	724	10,763	1900
1901	69	0.12	259	0.44	48	0.08	198	0.33	383	0.65	70	0.12	453	0.76	80	0.14	1,128	1.91	995	1.69	686	10,705	1901
1902	132	0.22	160	0.26	31	0.05	208	0.34	366	0 61	76	0.13	442	0.74	102	0.17	1,131	1.87	945	1.57	824	11,938	1902
1903	89	0.14	162	0.26	33	0.05	288	0.47	398	0.64	48	0.08	446	0.72	91	0.15	1,112	1.81	1,054	1.70	774	11,851	1903

fluctuations which mark the period prior to 1870 as compared with the less frequent and less violent fluctuations of the period subsequent to 1870, suggesting corresponding variations in the intensity of the cause.

As throwing light upon the causes of these fluctuations certain facts in the history of the city water supply and sewerage systems are of special interest. From 1832, the date of the completion of the first waterworks, until 1871 the intake for the public supply was at the foot of Dickson Street, not far from the present center of the city. In 1832, however, and for 20 years later, no public sewers had been built, the north part of the city was but sparsely inhabited, and the water delivered was comparatively free from pollution. But it was very limited in quantity, and for many years a large, if not the greater, part of the drinking supply was taken from wells which were uniformly shallow and easily polluted. In 1852 the first public sewer was built in Biddle Street, its outlet being about 1100 feet below the waterworks. In 1853, and again in 1855, the capacity of the works was greatly increased by the installation of 2 new pumping engines and the completion of 2 new reservoirs, and the general use of the public supply correspondingly increased.

Contemporaneously with this enlargement of the waterworks we note a very marked drop in the typhoid rate, which, with one upward turn in 1858-59, continued till 1861, when it reached 0.59 per 1000 as compared with 2.57 in 1851, a drop of 77 per cent. Meantime the building of sewers discharging into the river north of the waterworks had begun, and the sewage discharged by Rocky Branch and by Gin-Grass Creek, both in this district, was increasing. At the same time the typhoid curve takes an upward turn, which continues without interruption for 5 years, culminating in 1866, with a rate of 1.96 per 1000, or more than 3 times that of 1861.

The fluctuations of the next 4 years are without explanation in the condition of the water supply, so far as it can now be traced. For though the building of new waterworks in a new location was begun in 1866, and some efforts made in the meantime to improve the old supply, there were no changes in the former condition worthy of mention. But in May, 1871, the new works were inaugurated and the old works abandoned. The new intake was at Bissell's Point, which at that time was above the mouths of all the sewers. The new supply was also allowed to remain for 24 hours or more at rest in the new settling basins before its distribution to consumers, something which before then was impossible.

Coincident with this event the typhoid rate, which from 1869

to 1870 was rising, at once began to fall until, in 1878, it had reached a rate of 0.22 per 1000, a drop in 8 years of 78 per cent. After this, the rate, with some fluctuations, increased until in 1892 it rose in a single year from 0.36 to 0.93. Along with this rise from 1878 to 1892 there was a gradual introduction of sewage into the streams entering the river within the city limits above Bissell's Point; notably into the one nearest the intake pumps, namely Harlem Creek, which had become in effect an open sewer. That this was the chief, if not the only, cause of typhoid infection was so clear that the city authorities were induced to place a pump at Harlem Creek, by which the dry weather flow of the stream was delivered into the Ferry Street sewer, the mouth of which is below the Bissell's Point pumps. The immediate drop in the typhoid rate from 0.93 in 1892 to 0.44 in 1893 points clearly to the relation of effect to cause.

The Harlem Creek pump was maintained until the final abandonment, in 1895, of Bissell's Point as the source of supply and the inauguration of the present intake station at the Chain of Rocks, 6¾ miles further up stream, and above all present or prospective sewage originating in the city itself. During 1896, the first complete year after this last removal, the typhoid rate dropped to 0.16 per 1000 (or 16 per 100,000), the lowest recorded rate, and, no doubt, the lowest actual rate in the history of the city.

Since then the rate has increased until in 1903 it was 0.47 per 1000, or nearly 3 times what it was in 1896. The greater part of this increase has taken place since the opening of the Chicago Drainage Canal, January 17, 1903, the largest single increment, 0.13, having been made in 1903. That part of the increase was due to this new contribution of sewage there can be little doubt. But in view of the great potency of sewage at short range, as shown by the examples already cited from our own history, it is probable that we shall hereafter suffer more from the cities closer at hand, such as Peoria, Pekin, Quincy, Hannibal, Alton and St. Charles, than from Chicago.

Be this, however, as it may, it is certain that as the density of population on the watersheds above us increases the pollution of our water supply by sewage will at the same time, and in large measure unavoidably, increase, and with this will come an increase exposure to the infection of typhoid fever. Equally certain is it that complete exemption from this danger, with which alone we should be satisfied, is something that cannot be secured to us by any court, either State or Federal, but must be attained by our own efforts.

WASTE OF LIFE IN FORMER YEARS.

To those now living the progressive increase in the mean duration of life in St. Louis, disclosed by our inquiry, is very gratifying and hopeful. But when we look backward the figures disclose a serious waste of life which, with our present knowledge, might have been avoided. How great was this waste is shown by the following table, in which the actual mortality for the 6 complete decades ending with 1900 is compared with what it would have been for the same population at a rate of 18 per 1000, which is about the present rate.

Period.	Total Actual Deaths.	Total Deaths at Rate of 18 per 1000.	Difference or Lives Wasted.	Per Cent. of Lives Wasted.
1841-1850	26,778	8,735	18,043	65.83
1851-1860	46,832	21,826	25,006	53.41
1861-1870	61,424	36,697	24,727	40.26
1871-1880	66,385	54,593	11,792	17.76
1881-1890	82,660	72,822	9,838	11.90
1891-1900	96,422	93,122	3,300	3.42
Total	380,501	287,795	92,706	24.37

From these figures it appears that in the first decade the percentage of deaths that with better knowledge might have been avoided was nearly 66 per cent., and for the first 30 years was more than 50 per cent. For the whole 60 years the avoidable deaths amounted to 92,706, or 24.37 per cent. of the whole number. That is to say, the lives of this number of persons might have been prolonged, the extent of this prolongation being the difference between the mean duration of life corresponding to the rate of 18 per 1000 and that corresponding to the actual rate of 23.18 per 1000 for the whole period, or 12.42 years per person. This would have meant an addition to the sum of the city's life—its most valuable asset—of more than 1,150,000 years, all of which has in fact been lost.

A LOOK FORWARD.

From this study of what has been accomplished in the past we cannot help turning to the future with the question, How much further in this direction can we expect to go in the years to come?

Without doubt, there is a limit somewhere which we cannot pass. With every care the human frame will not last forever. Death cannot be abolished. And he would be a bold man who would do it if he could. For, as the world is now built, continued progress is dependent upon the constant influx of new lives with fresh vigor and new minds from which there are no past errors to be erased. Death, in fact, is the necessary condition of the world's higher life.

Something, however, can be done to make life longer, and much can be done to make it more vigorous and effective while it lasts. In particular, we may reasonably hope to still further reduce the rate of infant mortality, in which so much has already been accomplished. It is entirely probable that the present rate for this class in St. Louis, 4.5 per 1000 of the total population, may be brought down to 3, a saving of 1.5 per 1000. So, too, we may expect that the rate for consumption, a disease of the young and middle-aged, which is now 1.89, may be reduced to 1 per 1000, a saving of 0.89. Possibly the rate for pneumonia may be brought to the same limit, which would mean a gain of 0.69; and the typhoid rate ought certainly to be reduced to 0.1 per 1000, a further saving of 0.23. Summing these we have a total gain of 3.31 per 1000; which applied to the present rate for the years 1901-03, to wit, 17.71, leaves a resulting rate of 14.40 per 1000.

On the other hand, this saving, which is mostly of those in early life, will be somewhat reduced by an increase due to the diseases and casualties incident to middle and later life. So that a rate of from 14.5 to 15 per 1000, which corresponds to a mean duration of life of from 66⅔ to 69 years, is all that we can now reasonably hope for.

To attain this, however, will be no small accomplishment. It will involve a widespread knowledge of the conditions of health and universal compliance therewith. It will mean pure air, pure water and wholesome food for the whole people. It will mean that all must be protected and skillfully cared for when stricken.

But as population becomes more dense and the struggle for existence more arduous, this general sanitation will be a work of ever increasing difficulty. To hold our own will be no small task, to advance will be a great one, in which all classes must join and in which the engineer must bear a leading part.

DISCUSSION.

Dr. S. W. Abbott.—The paper of Engineer Moore, upon the "Vital Statistics of St. Louis Since 1840," is a distinct and valuable contribution to American vital statistics. The graphic method employed in showing the increase of population is indorsed by one of the foremost statisticians of modern times, Dr. Newsholme, in his "Vital Statistics," third edition, 1899, pp. 246 and 265. It is believed that this method was first employed by Milne, in his construction of the Carlisle life table, about 1789. Theoretically, the compound interest or geometric method is correct, because it recognizes the fact that the *increase increases.* Practically, however,

there are limitations which show that the actual rate of increase in large American cities lies between arithmetical and geometric progression. The graphic method also has the advantage of bringing out sharply the defects of such a census as that of 1870. A very interesting inquiry is suggested by the allusion to the effects of the Civil War. Great wars have always had a decided influence on the vital statistics of the countries involved, and especially upon the death rates and marriage rates of years of war. The following figures illustrate this fact:

Austria.			France.			Massachusetts.		
Years.	Persons Married, per 1000.	Deaths, per 1000.	Years.	Persons Married, per 1000.	Deaths, per 1000.	Years.	Persons Married, per 1000.	Deaths, per 1000.
1865	15.5	30.0	1869	16.5	23.5	1860	20.15	18.74
1866*	13.0	40.9	1870*	12.1	28.3	1861*	17.72	19.45
1867	19.3	29.2	1871*	14.4	34.8	1862*	17.69	18.45
			1872	19.5	22.0	1863*	17.36	22.15
						1864*	19.87	22.83
						1865*	20.62	20.64
						1866	22.14	18.14

* Years of war.

St. Louis appears to have suffered more severely than either New York or Boston in the cholera epidemics, and also in the great smallpox epidemic of 1872-73.

The comments upon the death rate from typhoid fever are worthy of special comment, especially the sentence beginning "But in view of the potency of sewage at short range." Undoubtedly, most of the great typhoid epidemics of recent years have arisen from "pollution at short range." Good legislation has decided influence in controlling the spread of typhoid fever. In Massachusetts, in the early half of the nineteenth century, the typhoid death rate could not have been below ten per ten thousand living. Only two cities of considerable size in the State were then supplied with public water, Boston and Salem, and this was sparingly furnished; but under the influence of rapid growth of towns and of legislation controlling water supplies and giving their general supervision to the State Board of Health, the typhoid death rate has been reduced as follows: In the decade 1856-65 it was 9.3 per 10,000; in 1866-75, 8.1; in 1876-85, 4.7; in 1886-95, 3.6; in 1896-04, 2.5. Fully ninety per cent. of the population now live in towns having public water supplies under State supervision.

There is yet another cause which has aided in the reduction of the general death rate in recent years beside the splendid effect of public sanitation, and that is immigration of great numbers of young

persons at healthy ages. The great mass of the population coming to our shores at the present time consists of young people between the ages of 15 and 35 years. These are distributed throughout the population of the States, and contribute to the reduction of the death rate, since the death rate of persons aged 15 to 35 is not more than 7 to 9 per 1000.

Mr. Allen Hazen.—Mr. Moore's very interesting statement as to deaths and causes of death in St. Louis is so complete that there seems to be little left to be said upon the subject.

The great increase in typhoid fever since the opening of the Chicago drainage canal is one of the notable features. Another point of great interest is that the reduction in the general death rate seems to be entirely in the deaths of children under five years of age, and that, excluding this class, the general death rate has not materially changed for many years.

It may be that a further analysis would modify this conclusion somewhat. That is to say, the death rate per thousand is high among very young and very old people, and is lower among those in middle life. It occurs to the writer that in the early years of the city the number of people in middle life was larger in proportion to the number of old people than it now is, and if so, an analysis of the results by age periods would perhaps show that the relative number of deaths of comparatively old people had increased and that the number of deaths of people in middle life had decreased. The writer has no direct evidence to support this theory, but it would seem that this matter should be investigated further before accepting the conclusion that there has been no change in the conditions affecting the death rate for that part of the population more than five years of age.

Dr. G. Baumgarten.—The co-operation of the sanitary engineer with the physician in the study of the life and health of the community is a characteristic and cheering feature of the modern development of the science of public hygiene. It is, nevertheless, a reproach to the medical profession that it was left to an engineer to undertake what a medical statistician should have done long ago. Warm thanks are due to Mr. Moore for this labor of love. The outcome of his analysis is of the greatest value to the community of St. Louis, especially as it is based upon a rationally corrected estimate of the population. The errors which still cling to this estimate probably can never be eliminated. A conspicuous one is apparent in the figures for 1849 and 1850: In the former year the great fire, the emigration to California during the gold fever and

the mortality by cholera alone of 4317 make it very improbable that the population had increased by 7260—*i. e.,* at a rate equal to the increase in the years preceding and following. Notwithstanding such details, the annual death rates here calculated can be utilized with confidence.

The same accuracy cannot be ascribed to the death rates of individual diseases, because the records of deaths from some of them are vitiated by faulty diagnoses. Thus the deaths from typhoid fever in the earlier years of this series are certainly understated, many being registered under other names, notably malaria, while they are more correctly recorded in recent years. Hence the annual death rate from typhoid fever can safely be said to have been greater than reported in the sixties and seventies, which makes the increase in 1882 to 1888 less abrupt than appears in the tables and its reduction in later years more satisfactory. Even in regard to consumption it is likely that many deaths were formerly reported under more innocent names.

The possibility of influencing the prevalence of pneumonia by such sanitary improvements as are within the scope of engineering science does not seem promising, and the death rate from this cause is increasing. It may be pointed out, however, that not only is this disease more correctly reported to-day than in former years, yielding larger figures, but since 1889 we have an additional source of pneumonia of the greatest importance in the annually repeated epidemic prevalence of influenza. The effect of this disease does not appear directly in the mortality records, because it becomes fatal only through its complications and sequelæ, and the deaths it causes are listed under the diseases of special organs and systems—pneumonia, heart diseases, kidney diseases and many others. But its value as a contributor to the general mortality cannot be overrated. This factor may well explain the rise of the death rate in 1890 to 1893.

Since it is impracticable, however, to "go behind the records," the tables which Mr. Moore has elaborated will probably stand as the authoritative vital statistics of St. Louis.

DR. JOHN GREEN.—The curve plotted by Mr. Moore illustrates the general trend of growth in great centers of population during the period which he has covered and, also, the effect of certain special causes which have notably retarded the growth of St. Louis during the middle decades of that period.

The general law of unrestricted increase in population, aptly designated by Mr. Moore as a case in compound interest, is exemplified in the curve as plotted from 1840 to 1860 and, again, from

1880 to 1900. For each of these periods the increasing steepness of the curve points to a growth, in geometrical progression, in which the annual rate is both very high and approximately constant. The effect of special conditions, interrupting the regular growth of St. Louis, is seen in the extreme flatness of the curve between 1860 and 1880.

The grossly overcharged enumeration of 1870 must be rejected as affording absolutely no guide to an estimate of the actual population of St. Louis in that year. As a check on this egregious fraud, the census taken by the city in 1866 is illuminating, but there is good reason for believing that its showing is somewhat below the truth. Possibly a very flat curve, approximating a straight line, connecting the points established for 1860 and 1880 and passing a little above the point indicated by the city census of 1866 to cut the ordinate for 1870 at about the point assumed in Diagram 1, thus smoothing out the small cusp shown at 1860, may represent the general flow of increase during this period with as near an approach to correctness as is attainable from the data at hand.

It would be interesting, were it practicable, to trace the fluctuations which must have occurred from year to year during the decade 1860 to 1870. That the opening year of the Civil War (1861) would show a notable depression scarcely admits of question. The remaining years of the war (1862 to 1865) were marked, on the one hand, by exceptional activity incidental to the establishment and maintenance of a great military depot and, on the other hand, by almost complete stagnation in building. The transition from war conditions to those of peace cannot have been altogether smooth, yet the city census of 1866 shows conclusively that the change was not attended by any remarkable disturbance.

Indirectly, the Civil War proved a most important factor in retarding the growth of St. Louis. The extension of great railway systems into new territory west of the Mississippi, involving a corresponding decline in river transportation, was already well under way in 1860. During the four years of the war the activity of St. Louis in the direction of readjustment to the rapidly changing conditions was suspended, to be resumed later at great disadvantage and with relatively tardy achievement. The progress made in this readjustment may be traced in an increased steepness of the curve, observable after 1880, and in the consecutive accessions in steepness after 1890.

The visible advances made since 1900 point to a continuing high annual rate of increase, as indicated in the tentative prolongation of the curve after 1900.

Passing to Diagram 2, in which the annual death rates are tabulated from 1841 to 1903, the year 1842 shows an unexplained low ratio of 26.67, as against an average of 52.44 for the decade and a half ending with 1855. Excluding the figures for 1842, the remaining fourteen years of this period show an average of 54.26, with fluctuations between the limits 38.14 and 120.30. These numbers point unerringly to the uncontrolled operation, between 1840 and 1855, of overwhelmingly unhygienic conditions, maintaining from year to year a fertile breeding ground for the propagation of pathogenic germs of many kinds, but all overshadowed by Asiatic cholera, which would appear to have been endemic during most of this period.

At 1856 the diagram shows a sudden reduction in the death rate, which was maintained through 1860; also a striking absence of conspicuous yearly variations from an average of 30.84. Cholera had disappeared, and there was a notable decrease in the deaths from typhoid fever. This was a time of active sewer construction, and the public water supply had been largely augmented and its distribution greatly extended. The growth of the residence section of the city westward, over previously unocccupied ground, an increased dependence on stored rain water in the place of that afforded by shallow wells, and a larger use of the then practically uncontaminated river water supplied by extensions of the city mains go far toward explaining the diminished ratio of mortality during this period.

The death rate (24.79) of 1861 is, with a single exception (23.08 in 1868), the lowest computed for any years of the first three decades (1841 to 1870) covered by Diagram 2. This low rate, tabulated between 30.96 for 1860 and 29.85 for 1862, may be interpreted as in support of other facts which indicate an actual decrease in population for this first year of the Civil War. The progressively higher ratios for 1862 to 1864, diminishing somewhat in 1865, find an explanation in the numerous deaths in the local military hospitals and in the great influx of refugees and negroes.

In the summer of 1866 St. Louis was visited by a grave epidemic of cholera, and the death rate for the year rises to 44.54. It was also a bad year for typhoid fever; in fact, the worst that has been recorded since 1854. In a less aggravated form the cholera was carried over to the next year, and sporadic cases occurred in 1868. Interpreted in the light of the medical knowledge of to-day, the facts observed during this epidemic afford a striking illustration of specific contamination of water drawn from shallow wells in polluted soil, which was still freely used in the older and more

crowded sections of the city and, although clear and pleasant to the taste, was, nevertheless, the principal vehicle for the dissemination of cholera germs, as it had long been for those of typhoid.

Since 1870 the sanitary conditions in St. Louis have been largely determined by the fact of the rapid extension of the city over new ground, outstripping the development of sewer systems and of water distribution; an extension stimulating and, in turn, stimulated by the extension of street railways and progressive improvements in methods of propulsion. A notable increase in the mortality of 1872, 1873 and 1875, due to epidemic smallpox and fluctuations in the death rate from typhoid fever, dependent on alternations of deterioration and improvement in the quality of the city water supply, teaches obvious lessons. The recently inaugurated work of the water department, in measurably clearing the distributed water of mud and living germs by coagulation and sedimentation, should bring about a diminution in the mortality from typhoid, and possibly some recognizable improvement in the general death rate of the city.

As the first to employ the graphic method in a comprehensive study of the vital statistics of St. Louis, Mr. Moore has shown the way to all future investigators in the same field of research. By no other method can the defects in recorded statistics be so clearly demonstrated, and, in certain cases, approximately corrected. As remarked by Prof. Henry S. Pritchett, in discussing the population curve plotted by him for the United States from the decennial census reports down to 1890, a prolongation of the curve affords the most trustworthy general guide for estimating probable future growths for periods of a few years. For purposes of interpolation throughout the intervals between periodical enumerations it is unquestionably the surest, as it is the simplest, method known.

Mr. Robert Moore.—The author is much gratified by the general concurrence of those who have discussed his paper in the methods used by him in his investigation. The concurrence of such men is a sure indication of what must be the general verdict.

The author also recognizes the justice of what has been said by way of criticism and qualification of some of the conclusions indicated by his investigation. These qualifications, however, are all due to omissions and imperfections in the data which are now beyond remedy. The age distribution of the population, particularly in the first three decades, cannot now be determined; nor can errors in regard to the causes of death be now corrected. We must make the best of such data as we have.

But while due allowance must be made for these imperfections, the main conclusions of the paper remain unshaken.

THE CLASSIFICATION OF ENGINES FOR BRIDGE LOADING.

By C. D. Purdon, Member of the Engineers' Club of St. Louis.

[Read before the Club, October 19, 1904.*]

This is more in the nature of a device for saving time and labor than a paper for a scientific club.

Upon any railroad of mature years there will, no doubt, be many iron or steel bridges of varying degrees of strength, having been built at different times, under different specifications and for different loadings. As the engines have maintained a healthy growth for many years, it is likely that some of the older bridges will be found rather light to carry the newer engines in regular service, although occasional trips may be safely allowed.

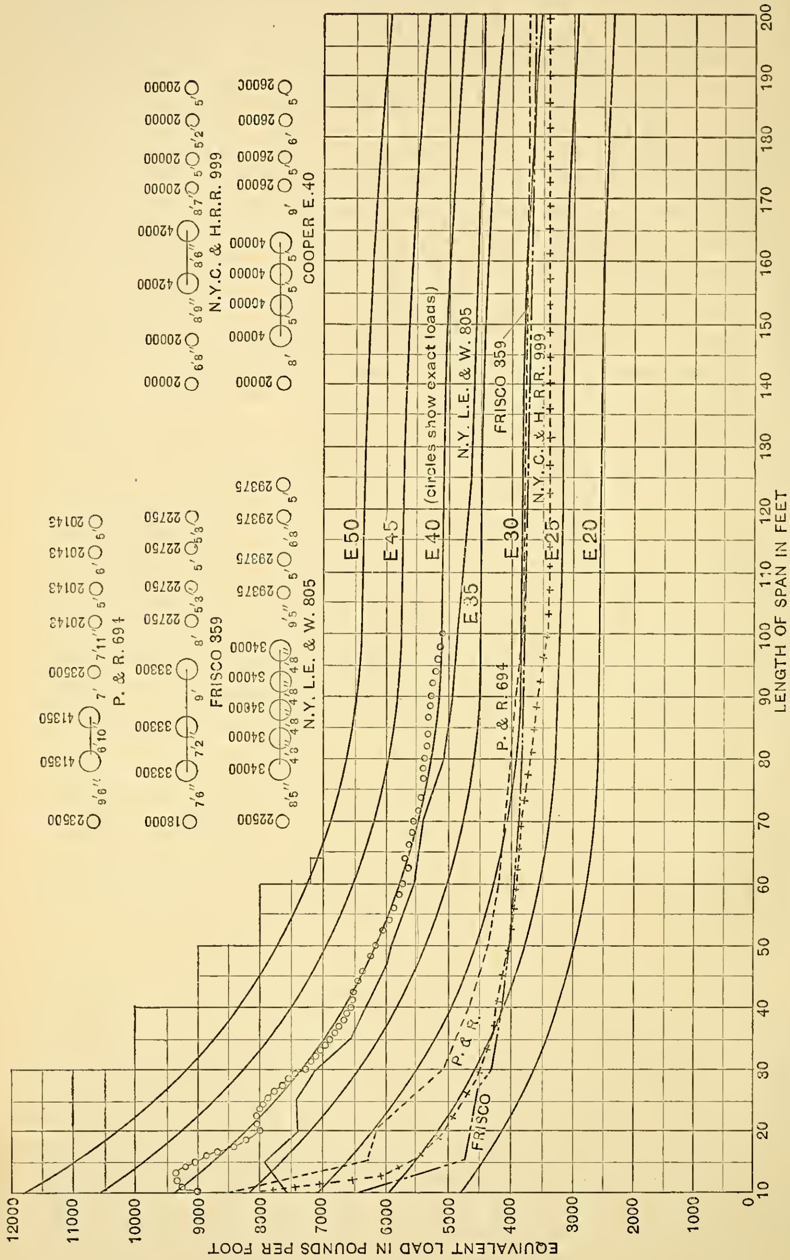
For this reason the receipt of messages from the operating department, asking whether engine number so and so can be run over such a division, "please reply by wire," is very common.

As an answer entails first getting the detailed weight and wheel spacing of the engine and then calculating more or less bridges for it (the original strain sheets having, in many cases, disappeared), it is very evident that some means of comparing the strength of the bridges with the weight of the engines is desirable, so that such questions can be readily answered and the superintendents furnished with lists showing what engines, if any, are barred from certain districts.

To attain this result the writer decided to classify the engines in use according to Cooper's specifications for bridges, the loadings varying by regular percentage, and to calculate all bridges for class 40; then, having the strain in any member induced by the loading of class 40, a simple proportion gives the strain for any other loading.

All of the engines in use are classified, and each new engine is classed as received. This is done by calculating the moments for the concentrated loads for different lengths of spans and then finding the load in pounds per lineal foot which will produce the same moment. Taking as typical spans deck girders up to 90 or 100 feet in length and truss spans for greater lengths as the moment is equal to the weight per foot, multiplied by the square of the length in feet and divided by eight, it is a simple matter to find the equivalent load by multiplying the moment by eight and dividing by the square of the length.

* Manuscript received November 7, 1904.—Secretary, Ass'n of Eng. Socs.



Classification of Engines for Bridge Loading. Diagram Showing the Equivalent Load in Pounds per Lineal Foot which Produces the Same Moment as the Engines. One-Third of Full Size. The Original Diagram is Divided to 1 Foot of Span and to 100 Pounds of Load per Foot.

For truss spans the panel coefficient is used. This may be found in Waddell's "De Pontibus," page 370; for instance, in a five-panel truss the moment in the center panel of bottom chord is three panel loads; therefore the equivalent load is the moment divided by three times the square of the panel length.

A diagram of Cooper's different loadings is prepared, showing a curve for each loading, varying by five; by platting on this diagram the equivalent loads for any engine, the class of the engine is at once shown.

The drawing attached shows this diagram, showing loadings 25, 30, 35, 40, 45 and 50. These were platted by taking the equivalent loads for class 40 from the table in the American Bridge Company's specifications, platting the loads as shown by the small circles and averaging them with a curve. The other loadings are proportional to 40.

Upon this drawing are shown the weights and wheel spacing of a few engines of different types for illustration, the equivalent loads being shown on the diagram.

Engine 999, N. Y. C. & H. R. R., would be class 40 on very short spans, falling to class 25 at 16 feet, and remaining in this class up to nearly 40 feet, then remaining about class 27.

Engine 694, P. & R., is practically class 30, except on very short spans.

Engine 359, Frisco, begins with class 33, falls to 22 at 15 feet, rises to 25 at 40 feet and 30 at 90 feet and over.

Engine 805, N. Y., L. E. & W., runs between 30 and 40.

It is evident that any number of classes can be made—practically advancing by five will be sufficient, except perhaps for classes over 30, when closer figures may be desirable.

Having the engines classified, a list of the bridges on each freight division—now known as a "district"—is made, giving the number, length and a very brief description, together with the strain per square inch induced in the weakest member by loading 40.

A short inspection of this list, with the class of the engine, will give the strain in the weakest member.

It is hardly necessary to say that the number of the loading in Cooper's specifications means the weight in thousands of pounds on each driving axle. For instance, class 40 has 40,000 pounds on each of four axles, class 30 has 30,000, etc., the wheel spacing in each case being the same and all other axle loads being in the same proportion as the driving axles.

A list is furnished each superintendent, trainmaster and dispatcher, showing the class of every engine, and the heaviest class

to be used in regular service on any district, the latter divided into two columns; one column giving the class as limited by iron bridges, the other the class as limited by trestle bridges.

This list fixes the heaviest class for regular service. If for any reason it is desirable to move a heavier engine over any district, the superintendent wires for information. With the list and diagram an answer is readily given.

Unfortunately there is no royal road to classify the engines—each one has to be calculated by itself—though in many cases there is sufficient similarity to classify one engine by comparison with others already classified.

The writer calculates moments for each 5 feet in length up to 50 and each 10 feet 50 to 90 feet, taking the center moment of a beam or deck girder; beyond 100 feet in length the center panel moment of bottom chord in truss spans of 25-foot panels, increasing by one panel length, or 25 feet.

While a good deal of labor is necessary for these calculations, when once made in this shape they are always available for instant reference, so that in the end time is saved.

This method of classification meets with the approval of all departments of the system with which the writer has the honor to be connected, and the mechanical department give the bridge class of engines in all their lists, so that all parties are advised of it.

A sample sheet of bridge list is given below, merely to convey the idea. It is evident that to find the effect of any engine on these bridges its class on a 12-foot span for bridge 96, and 18-foot span for bridge 122, would be the governing weight.

BRIDGE LIST.—OMAHA DISTRICT, WESTERN DIVISION.

Number.	Length.	Description.	Strain per Sq. Ft. Class 40	Remarks.
82	40	Deck girder	9,200	
96	62	Through-girder, 5 panels	11,000	On stringers.
118	40	Deck girder	9,800	
122	160	Through-truss, 9 panels .	10,500	Hip vertical; pins small and worn.

Trestles, 14-foot panels; stringers, 2 panels, 8″ x 18″. Fibre strain, 1450 from class 40.

ERRATUM.

Journal of the Association of Engineering Societies, Vol. XXXIII, No. 5, November 1904, page 328, table at foot of page (Bridge List), heading of 4th column. For Strain per Sq. Ft., Class 40, read Strain per Sq. In., Class 40.

OBITUARY.

Charles William Folsom.

Member of the Boston Society of Civil Engineers.

Charles William Folsom was born in Cambridge, Mass., April 17, 1826. After attending various schools in his native place he entered Harvard College at the age of fifteen, and was graduated there in 1845, receiving the degree of A.B. Among his classmates were the late George P. Bond, Director of the Astronomical Observatory, and Horace Gray, Associate Justice of the United States Supreme Court.

From 1845 to 1848 he was acting civil engineer for the Essex Company, at Andover, being associated with the late Charles S. Storrow in the construction of the dam across the Merrimac River at Lawrence, and a part of the year 1848 he had a similar position on a railroad in eastern New York.

In 1852 he was division engineer on a preliminary location of the Pittsburg, Maysville & Cincinnati Railroad under Robert McLeod, chief engineer, with headquarters at MacConnelsville, O. In 1853 and 1854 he was engaged as assistant on the Nova Scotia Railroad, and later on the St. Peter's Canal under direction of the Government of Nova Scotia. He was also employed in engineering on the Midland Railroad, in Charlotte County, Virginia, and for two years was assistant superintendent and master of transportation on the Rutland & Burlington Railroad, Vermont.

In 1860, with the late R. M. Copeland, he opened an office in Boston for landscape gardening and civil engineering.

On the outbreak of the Civil War he received a commission, July 1, 1861, as quartermaster in the Twentieth Massachusetts Volunteer Infantry, of which Wm. Raymond Lee was then colonel, and the lamented Gen. W. F. Bartlett was then a captain. He was in many engagements and often under fire, though at all times acting as quartermaster,—at one time as brigadier quartermaster of the Third Brigade, Second Division, Second Corps. March 13, 1865, he was promoted to captain and assistant quartermaster United States Volunteers, and brevetted colonel. Among his comrades there are told many stories of his unofficial kindness and his unusual application to his duties. From May to November, 1865 he served as chief quartermaster of the district of the Nottoway, Virginia, in the Department of Petersburg; and he continued in the army for three years afterwards, until his honorable discharge, August 31, 1868, his last duties being in the office of the quartermaster-general, United States Army, Washington, D. C., where he had charge of the

Department of National Cemeteries. He had the unanimous indorsement of all his superiors, up to and including Quartermaster-General M. C. Meigs, for transference to the United States Service.

In 1869 he was receiver for the Alexandria, Loudon & Hampshire Railroad Company, in Virginia, and of the East Tennessee & Virginia and the East Tennessee & Georgia Railroads, in Tennessee. In 1870 he was assistant engineer of Boston, and for three years thereafter superintendent of Mt. Auburn Cemetery.

From 1873 until recently he was employed in the sewer department of the city of Boston, except that in 1881 he was principal assistant engineer of the Elk River Railroad, in West Virginia, under the late Thomas Doane, and in 1885 he was for a time employed as an engineer by the Massachusetts State Commission on Drainage and Water Supply of the Charles and Neponset Rivers.

His principal work for the Sewer Division of Boston was the preparation of topographical maps, from original surveys, of the outlying districts Dorchester, West Roxbury and Brighton. These maps are the best in the department, and practically the only complete ones, and are relied upon in the design of new systems of sewers and in the settlement of disputes and suits in which the determining consideration is the original location of natural water courses.

He also projected and superintended the construction of the most important main sewers and surface drains in these districts, and had charge of the general engineering work of a district.

He died in Cambridge, May 19, 1904, and was buried at Mt. Auburn.

Col. Folsom, as he was always called, took great interest in the affairs of the Boston Society of Civil Engineers and was a frequent attendant at its meetings.

His reputation for skill and accurate work in his profession was very high, and his subordinates will also gladly bear witness to the patience and consideration he showed them in their various relations.

A man of literary as well as scientific tastes, he was always a pleasant companion, having a fund of general information and knowledge of many interesting people.

Too modest to obtain the highest prizes of this world, he deserves to be long remembered for the strict integrity of his character and his unselfish and unblemished life.

Charles W. Kettell,
W. H. Bradley,
Edgar S. Dorr,
Committee.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIII. DECEMBER, 1904. No. 6.

THE WATER SUPPLY OF MINNEAPOLIS.

BY J. FRANK CORBETT, M.D., BACTERIOLOGIST, MINNEAPOLIS BOARD OF HEALTH; PROFESSOR OF BACTERIOLOGY, HAMILINE MEDICAL COLLEGE.

[Read before the Engineers' Club of Minneapolis, October 10, 1904.*]

BEFORE coming to the discussion of the subject of this paper it is important to explain the relationship between colon bacilli and typhoid bacilli. The cause of typhoid fever, the typhoid bacillus, is present in the intestinal dejecta and the urine of typhoids. As typhoid is a very common disease, any water containing fecal matter is liable to contain typhoid bacilli. These bacilli are capable of living for a long time in water. If such water be drunk, typhoid fever is the result. Statistics have shown that the drinking of a water constantly contaminated with human fecal matter invariably results in typhoid fever. The amount of sewage may be imperceptible to any of our senses. A single case of typhoid fever has infected the water supply of a whole city by depositing dejecta on the shores of a reservoir.

The typhoid bacillus is difficult to demonstrate in water, but if fecal matter be present in water, so universal is typhoid, the water is not fit for use.

As the colon bacillus is derived only from the intestinal contents, bacteriologists assume the presence of colon bacilli to indicate fecal contamination.

The water supply of Minneapolis is derived from the Mississippi River. There are four pumping stations. Two of these—the North Side Station and the Northeast Station—are located at the

* Manuscript received October 21, 1904.—Secretary, Ass'n of Eng. Socs.

outskirts, before the river enters the city. The water from these stations receives little or no direct contamination from our own city. The lower stations are known as the East and West Side Stations. These lower stations are located in the heart of the city and receive the water below the outfalls of several large sewers. Both lower stations have been closed by the Water Board.

In Minneapolis, colon bacilli are constantly found in the water of the lower pumping stations, and occasionally in the water from the upper stations. A chart prepared by Mr. F. W. Cappelen shows an increase of typhoid during the years when the lower stations were used, and a decrease when they were not used. Dr. P. M. Hall has also collected statistics showing the water supply from month to month and the invariable rise of typhoid following the use of the East and West Side water.

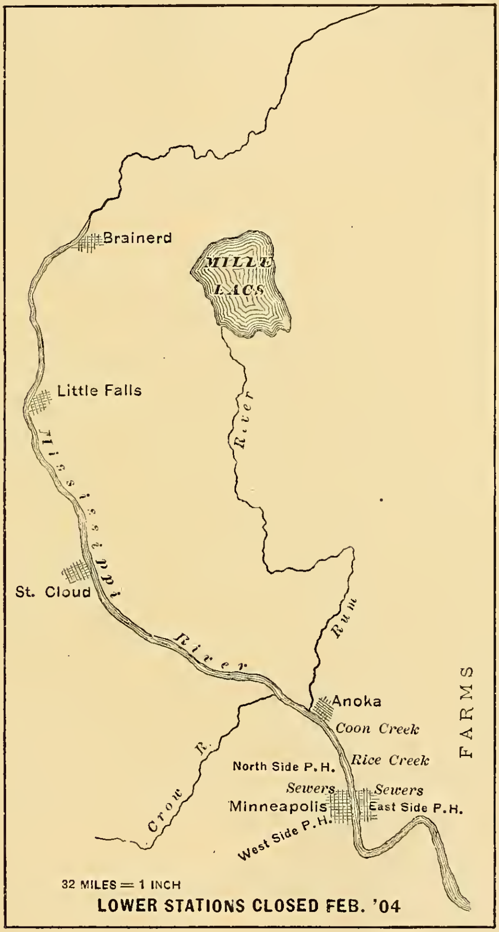
In chart No. 1 the black line represents the number of deaths from typhoid for each month from January 1, 1903, to September 30, 1904. The dot and dash line represents the amount of water supplied from West Side Station; the underscored dotted line indicates the amount of water from the East Side Station.

It will be seen that following the use of the East Side Pumping Station there is an immense rise in the typhoid line. An analysis of the cases shows that the typhoid was almost entirely in that portion of the city supplied by the East Side pumps. Before this, when the West Side pumps were running, the preponderance of cases had been on the territory supplied by the West Side water. When the West Side Station was closed and the North Side water turned on, the typhoid diminished in the same area. Also after the East Side pumps were stopped and North Side water supplied, the typhoid diminished in the East Side area. This shows the water from the lower stations to be a prolific source of typhoid.

Further analysis of the chart shows that we had a considerable rise of typhoid fever cases in February and March of 1903. As no water had been pumped from the lower stations for four months, we cannot charge this increase to them. These cases must have originated either from the North Side water, or from contaminated wells. That the North Side Station was responsible at that time is probable from the fact that above our pumping station in the Mississippi River are located Anoka, Little Falls, St. Cloud and Brainerd. Except Anoka, all these cities have sewers emptying into the Mississippi River, and typhoid was prevalent in these cities before that time. Further than this, the cases were largely in a portion of the city that uses river water. General distrust in city water has resulted in many surface wells being used. In 1898,

1899 and 1900, over 50 per cent. of typhoid came from the use of well water. The action of the Board of Health in closing these infected wells has diminished the return from this source.

In February, 1904, a commission, consisting of Messrs. Cappelen, Rinker and Hazen, was appointed to investigate the water supply of Minneapolis. The writer of this article was requested by



the commission to make certain analyses. The results of these analyses have been incorporated in the accompanying charts.

Chart No. 2 shows the relative number of bacteria in river water and in the same water after being allowed to sediment in the reservoirs. From this it is seen that sedimentation removes a considerable per cent. of bacteria, and tends to diminish the number of

colon bacteria. The colon bacilli are found much more frequently in the river water than in the reservoir. Originally on this chart we represented analyses from both upper stations and the upper bay. As these analyses gave results almost identical on each and every day, we represent only one station on the chart.

In chart No. 3, we have represented the analyses of water taken from various parts of the Mississippi River. The height of columns indicates total number of bacteria per cubic centimeter; the lighter gray columns indicate the absence of colon, the black columns the presence of colon bacilli. From this it will be seen that there is no material change in the water until we reach Brainerd, and that there is a direct rise in the number of colon bacilli as we pass cities and towns, and that they tend to disappear as we recede from centers of population. This diminution is not due to mere mechanical agitation, but probably to dilution and to action of algæ, etc.

There is an immense rise in the total number of bacteria when we reach the lower stations. The colon bacilli can be demonstrated in the very smallest amount of water used from this location.

In this chart are represented, also, the analyses of the tributaries of the Mississippi. In the Mille Lacs analyses we find very pure water in the main lake. In the bays and near the shores we find already slight contamination, as indicated by presence of colon. This region is being rapidly settled and the amount of contamination is bound to increase. Although Mille Lacs is a beautiful body of water, 30 miles across and sufficiently deep, yet close settlement would render it unfit for use. In addition, the presence of certain algæ in the water presents a serious problem. It has been found that the presence of these algæ in water render it unpleasant on account of odor. They ordinarily exist in small numbers and do not cause trouble, but when put under proper conditions they multiply and are a source of annoyance. The storage of water in shallow reservoirs favors their development in certain seasons. It is possible that certain traditions of dead fish, causing the lake to smell, may be due to these algæ.

We isolated the following species, which in large numbers give rise to disagreeable odor:

Clathrocystis,
Anabaena,
Oscillatoria,
Asterionella,
Navicula.

The outlet of Mille Lacs is the Rum River. The Rum River remains tolerably free from contamination until it reaches Anoka.

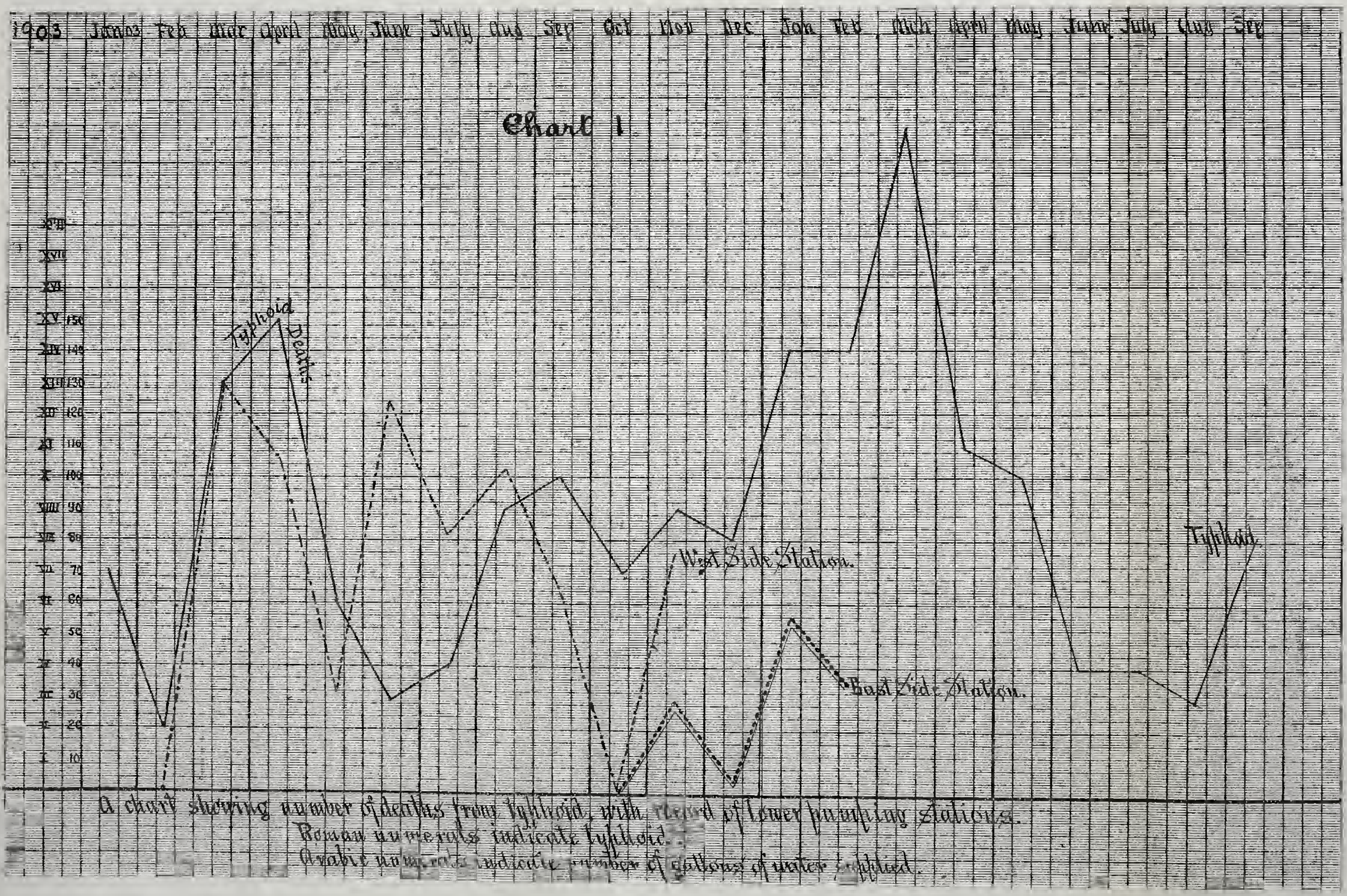

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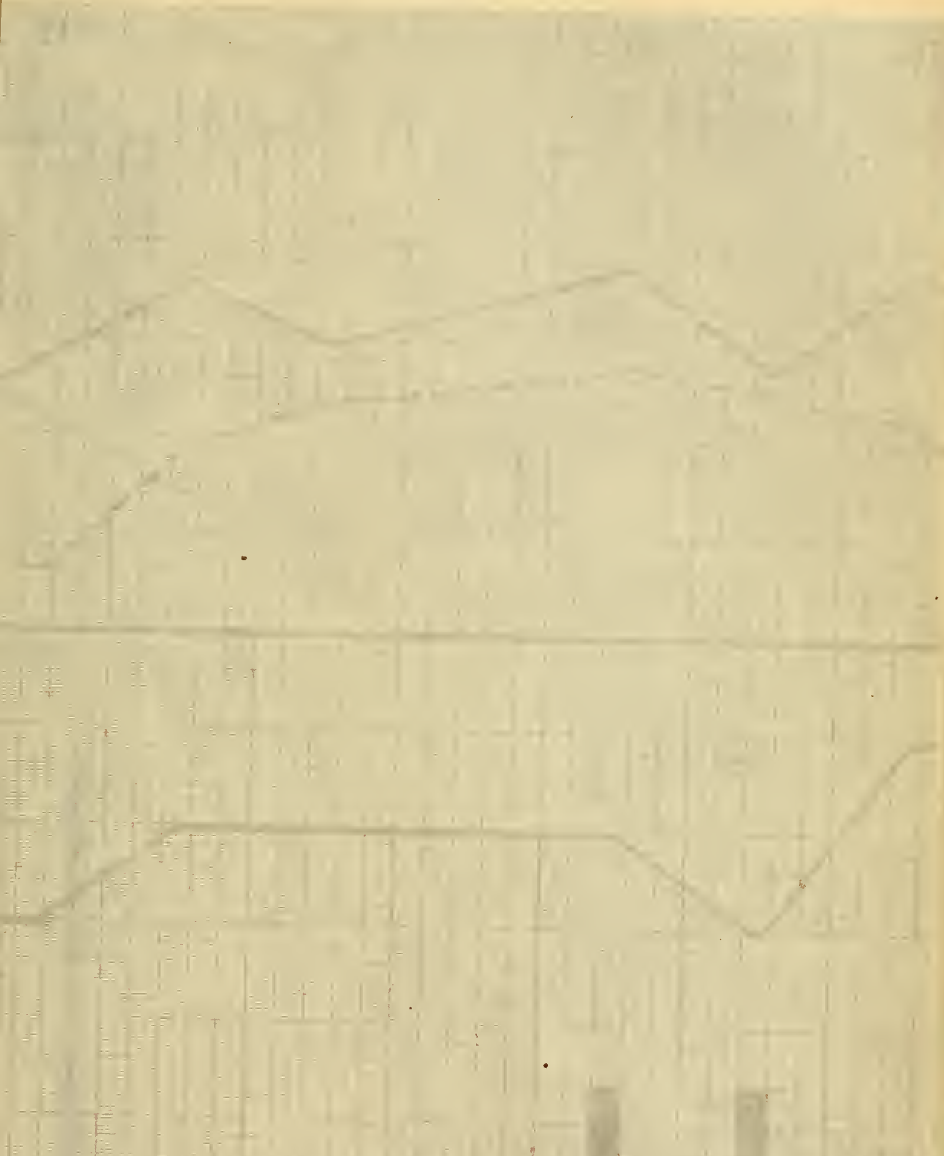
Chart 1
Typhoid Deaths
West Side Station.
East Side Station.
Typhoid
A chart showing number of deaths from typhoid, with record of lower pumping stations.
Roman numerals indicate typhoid.
Arabic numerals indicate number of gallons of water supplied.



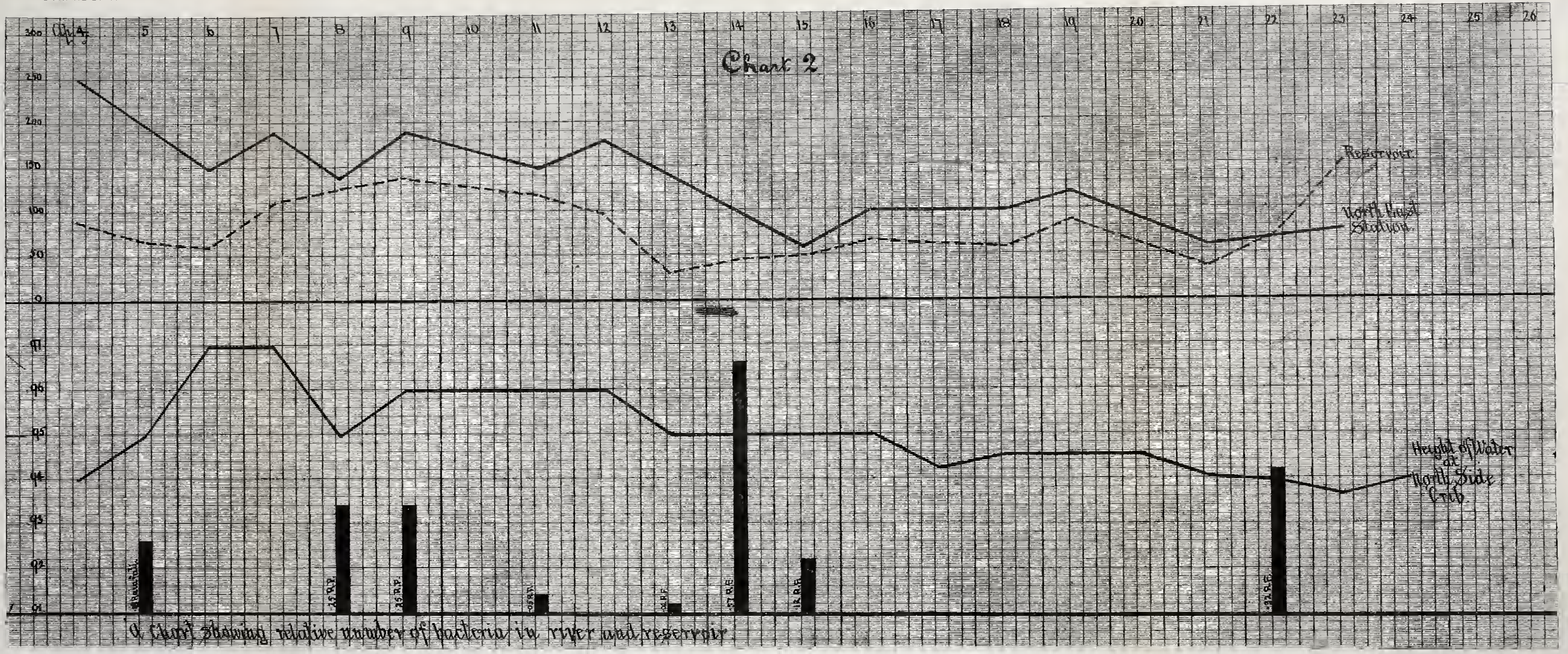
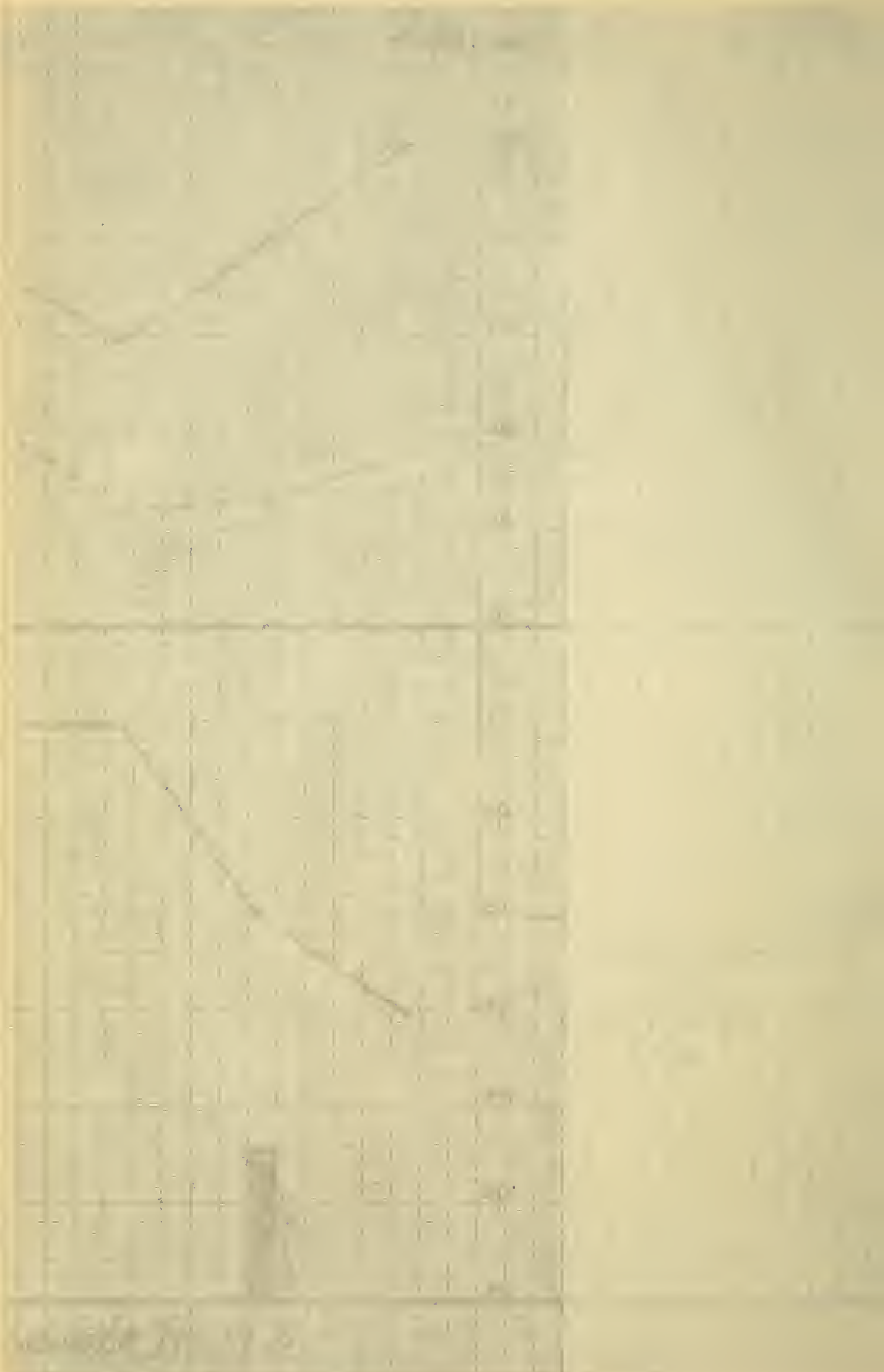
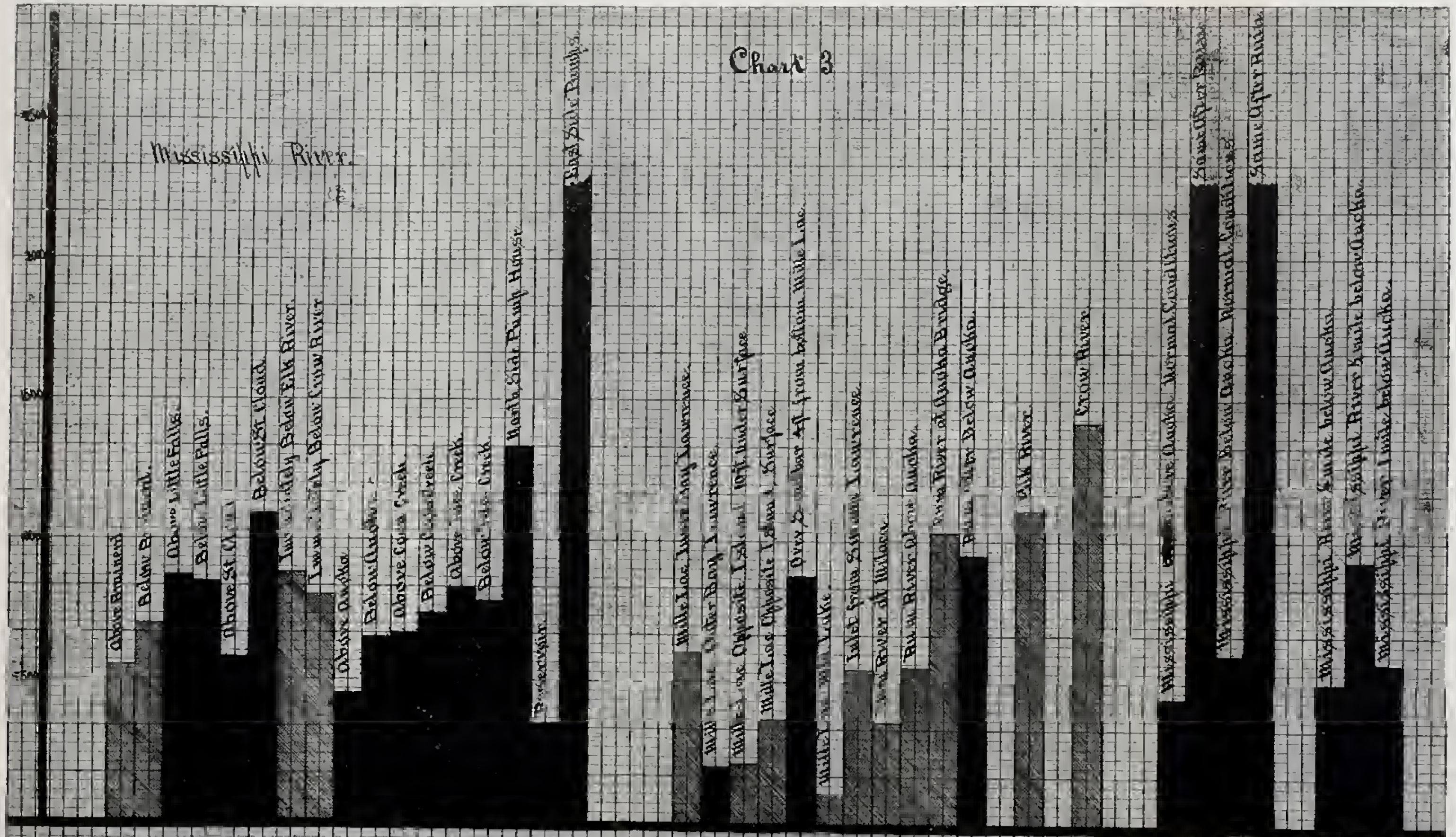


Chart 2
Reservoir
North Point Station
Height of Water at North Side Crib
A Chart showing relative number of bacteria in river and reservoir





A CHART SHOWING RESULTS OF BACTERIOLOGICAL ANALYSES OF WATER.

Height of Columns Indicates Total Number of Bacteria per Cubic Centimeter.

Black Indicates Colon Bacilli.

Although Anoka has no sewer system, it is apparent from the charts that the refuse is washed into the Mississippi River by rains. In the next to the last series the effect of this is shown. After heavy rains the water is much more highly contaminated than before. This statement is based on samples of water collected on six different dates. It should therefore be reliable. In the Mississippi River, above Elk River, only one set of samples was collected. Below this point the charts represent a series of six different expeditions.

The analytical work was done by Messrs. Swinnerton, Woodworth and Corbett.

A RECENT VISIT TO TWENTY-FOUR BRITISH SEWAGE WORKS.

By M. N. Baker, Associate Editor of the Engineering News.

[Read before the Sanitary Section of the Boston Society of Civil Engineers, October 12, 1904.*]

Mr. Chairman and Members of the Sanitary Section of the Boston Society of Civil Engineers: It was my great pleasure, shortly before I left this country for England, to attend the session of your section at which you discussed the septic tank and its relation to sewage disposal. I was very glad indeed to have that opportunity to hear from so many of the most experienced men in this country—the brightest minds in sewage works practice—immediately before going abroad to study the same general subject. It helped to freshen and inform me in regard to American conditions and has made it much more profitable for me to compare American and English practice.

On receiving the request to be with you to-night, I supposed that an informal talk was expected, but later I saw that the notices for the meeting read that I would present a paper. I propose to compromise by presenting a portion of what I have to say from a manuscript and supplementing it with more informal remarks.

I shall be glad to answer any questions, even in the progress of what I have to say, if it will add to the clearness of my subject.

Having been given a roving commission to go abroad for the general purpose of studying municipal conditions, I found it profitable to devote most of my time to British sewage purification works. Well provided with letters of introduction, I arrived in London on March 8, 1904. In that city I spent several weeks calling on a number of men and getting my bearings. On March 9 I called on Dr. Samuel Rideal, a leading chemist, and author of one of the best British books on sewage treatment by the later methods. He gave me a hearty welcome and some notes of introduction which proved of great service to me. Mr. Arthur J. Martin, one of the three engineers who introduced the septic tank in England, received me most kindly that same day and did much for me while I was abroad.†

* Manuscript received November 21, 1904.—Secretary, Ass'n of Eng. Socs.

† Mr. Martin, I may interject, was in this country for several years, in Schenectady, and he spoke very kindly of the treatment accorded him by the American engineers and others; and he, as well as a number of other persons whom I met, expressed themselves as wishing to do what they could for me, because they had been so kindly treated by Americans when they had been in this country.

I remained in London more than two weeks, meeting Mr. W. J. Dibdin, who developed the contact bed, and Dr. Frank Clowes, chemist of the London County Council, who succeeded Mr. Dibdin in that office and carried on the famous London experiments on the treatment of sewage in septic tanks and contact beds. Later and elsewhere I met Mr. Donald Cameron, of Exeter; Dr. Gilbert J. Fowler, of Manchester; Mr. John D. Watson, of Birmingham; Lieutenant-Colonel Alfred Jones, of the Aldershot Camp Sewage Farm, and many other engineers and chemists who have contributed largely to the progress of sewage treatment in Great Britain.

The twenty-four sewage works which I visited while in Great Britain ranged in size from the two plants which treat the sewage of the County of London, with its 4,500,000 people, to the small works of the Sandhurst Military Schools, serving about 1000 persons. Nine of the places visited had populations of more than 100,000 each. While I saw only a few of the numerous municipal sewage works in Great Britain yet 8,500,000 people were tributary to those works. In contrast to these figures it may be noted that Mr. George W. Fuller stated in his recent paper before the International Engineering Congress that there are about 1,100,000 people tributary to the sewage purification works of the United States.

The methods of treatment which I saw included plain sedimentation, chemical precipitation, broad irrigation, straining, intermittent filtration, the septic tank, contact beds and percolating filters, some alone but mostly in combinations of two, three or more processes. Scarcely any two plants were alike; or, to put it otherwise, there were family resemblances only. The works most closely resembling each other were those depending wholly upon either chemical precipitation or broad irrigation, or else the three built under agreements with the Septic Tank Syndicate. On every hand, new or modified processes had been or were being tested on an experimental or a working scale. Most of the works installed years ago had changed or were changing to some one or more of the so-called bacterial processes, and most of the recently conceived works were of the same kind. But I expected to find, and did find, a notable proportion of works true to the old British tradition of either chemical precipitation or sewage farming, notwithstanding the hurrah over septic tanks, contact beds and percolating filters. Sewage farming, I should say, has been less shaken by the new methods than has chemical precipitation. At least, chemical precipitation appears to be more a matter of toleration than does sewage

farming; the latter, where already in use under naturally favorable conditions, not being so eagerly abandoned as the former for some new process.

One important fact that should be borne in mind by those who are considering the newer methods of sewage treatment in England is the enormous difference in the soil of England and America, and particularly this part of America. English engineers have been absolutely driven into seeking other means of treating sewage than applying it to land, because the land is so very unsuitable for the purpose of sewage treatment. Those of our American engineers who have been abroad and familiarized themselves with foreign conditions have come back to this country quite conservative about recommending the introduction of British methods. Some of our American engineers who have not been abroad, but have confined themselves to reading literature on the subject presented in the English journals—literature usually in the form of papers read before the various sanitary and other associations and often by advocates of particular processes—have had a tendency to be carried further by the foreign practice than those who have been abroad, and therefore it seems to me that they have recommended the introduction of some kinds of British treatment in places where they were not called for, and where probably American lines of treatment would have been more suitable. In many of the densely populated districts of England, sandy soil is notable by its absence, and the clayey soil on which the people of that country try to treat sewage is enough to appal any engineer. The manner in which they have constructed and operated some of those works really fills one with admiration that men could contend so successfully against such odds.

The most marked impression made upon me, particularly during the first part of my stay in Great Britain, was that nothing regarding sewage purification in that country seemed to be generally accepted as settled. True, a large number of people look upon both chemical precipitation and sewage farming as things of the past, quite superseded by the so-called bacterial processes; but if you visit British sewage works at random, you will find many sewage farms and chemical precipitation plants still in use, and, as to the newer processes, no agreement even among their friends as to which is the best. Examine septic tanks and you will find some open and some closed (although the open ones seem to be most in favor) and no common practice as to frequency of cleaning and means of sludge disposal. With contact beds and percolating filters there is

even more dissimilarity and uncertainty in design, choice of material or medium, method of operation and unit rate of working.

Such confusion in theory and practice came as a surprise to me. I had not expected to find everything settled, but I looked for some prospect of agreement as to both methods and details of carrying them out.

The more I have reflected upon what I saw, the more I have come to believe that the confusion in British practice is more apparent than real; that, so far as it exists, it relates more to minor details than to essential processes; that the multifarious differences in detail may be largely attributed to the fact that there are many ways of achieving the same end and also to the mastering desire of the British health officer, chemist and engineer (particularly the first and second) to become known as an originator of a new method of treating sewage.

My early impressions of confusion abroad will be excused, I trust, as I review, in chronological order, the works I visited in Great Britain. After I have regrouped the works by the only classification of processes I have yet dared to attempt and made some comments on my summaries you will see how my ideas have, as I hope, become somewhat clarified.*

The accompanying table presents, in chronological order, the sewage works visited, their tributary population, and a condensed statement of the method of purification employed. The latter is, in many instances, incomplete and in some cases misleading, because of the variety of methods in use and the changes in progress. I shall now attempt to bring out some of the most interesting features of the various works.

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* I have elsewhere summarized what I found at most of the British works visited, arranging the summaries in order of population of the cities and towns concerned. (*Engineering News*, April 21, 1904.) In still another place I have described at length all the works visited, grouping them in accordance with the method of final treatment employed. ("British Sewage Works, and Notes on the Sewage Farms of Paris and on Two German Works"; published in October, 1904.) For the sake of variety and interest, I here take up in chronological order the several British works visited, and to avoid repetition of matter fully presented in my book, I make little use of statistics and of detailed descriptions.

British Sewage Works Visited, with Tributary Populations and Methods of Treatment Employed.

London	4,536,000	Chemical Precipitation.
Sutton	17,000	Septic Tanks and Contact Beds.
Reading	72,000	Sewage Farming.
Sandhurst Military Schools..	1,000	Sewage Farming.
Aldershot Camp	25,000	Sewage Farming.
Aldershot Town	17,000	Contact Beds followed by Intermittent Filters.
Birmingham and District...	793.000	Settling Tanks, Septic Tanks, Dortmund Tanks and Percolating Filters.
Salisbury	18,000	Septic Tanks, Percolating Filters and Rapid Secondary Filters.
Exeter	48,000	Septic Tanks, Contact Beds and Land Treatment.
Yeovil	14,000	Septic Tanks, Contact Beds and Land Treatment.
Manchester	545,000	Chemical Precipitation being replaced by Septic Tanks and Contact Beds.
Salford	220,000	Chemical Precipitation, Roughing Filters and Percolating Filters.
Rochdale	84,000	Roughing Tanks, Chemical Precipitation, Contact Beds, Percolating Filters and Land Treatment.
Chadderton	25,000	Chemical Precipitation and Contact Beds.
Oldham	140,000	Sedimentation and Contact Beds.
Accrington and Church	50,000	Septic Tanks and Percolating Filters.
Burnley	97,000	Sedimentation, Septic Tanks and Contact Beds.
Glasgow	780,000	Chemical Precipitation.
Barrhead	10,000	Septic Tanks and Contact Beds.
York	78,000	Chemical Precipitation and Percolating Filters.
Leeds	444,000	Chemical Precipitation.
Nottingham	240,000	Sewage Farming.
Leicester	200,000	Sewage Farming.
Hampton	7,500	Hydrolytic or Septic Tank and Contact Beds.
Total	8,461,500	

I will now try, without going too much into detail, to bring out the more interesting features of these works.

At London are the largest sewage works and the largest chemical precipitation plants in the world. The two plants are treating very nearly 300,000,000 United States gallons per day by chemical precipitation. Plans, however, are being made to abandon chemical precipitation. I think that there is some difference of opinion among those in authority in London as to the advisability of carry-

ing out the scheme recommended in the recent summary of reports published by Dr. Clowes, of London. Dr. Clowes and Mr. Worth, one of the engineers in charge of the London sewerage system, both informed me, as I understood them, that it was practically settled that as soon as possible septic tanks and contact beds would be established. I made this statement in a letter that I wrote for publication in this country. But subsequently Mr. Fitzmaurice, Chief Engineer to the London County Council, wrote a very sharp letter denying that they were committed to these new processes. New methods of sewage treatment have been under discussion in London a great many years, and it may be that they will continue to be discussed for some years to come.

I had a very interesting experience in going to visit the London works. I was taken down the Thames in the "Beatrice," a steamer owned by the London County Council, in company with the chemist in charge of one of the works. Every week some representative of the London County Council takes this trip down the Thames from London Bridge, or thereabouts, to Barking and Crossness and even further down the river. At frequent intervals samples of the water are taken and analyzed on the boat. This practice has been kept up weekly for a number of years, thus accumulating data regarding the changing conditions, if any, of the Thames, both above and below the present sewage works.

At Sutton, as many of you know, Mr. W. J. Didbin has a residence, was at one time on the local town council, and put in the first, or about the first, contact beds. He was carrying on investigations at the time for London, and put down these contact beds to treat the flow of the sewage by this method alone. Later, and independently of Mr. Dibdin, what he calls grit or detritus chambers have been built. Curiously to me, and I think to most of you, Mr. Dibdin urged that inasmuch as the patented methods of the Septic Tank Syndicate were not followed at Sutton it was wrong to apply the term "septic tanks" to those tanks; but the foreman of the works called them septic tanks, septic action was in progress, and I call them septic tanks, although in my book on "British Sewage Works" I put in a footnote explaining Mr. Dibdin's attitude on the subject.

Additional contact beds were being constructed at Sutton at the time of my visit, but on somewhat different lines from those that Mr. Didbin had employed; that is, they were putting in triple contact beds, arranging to pass the sewage successively through three sets of beds and have a total fall of only some 18 inches from the point of entry to the first bed to the discharge from

the last one; and they were using, as is commonly used at many places, automatic apparatus for controlling the discharge from one bed into another. The changes and extensions at Sutton have been and are being carried out by Mr. C. Chambers Smith, surveyor to the Sutton Urban District Council.

At Reading I saw a large sewage farm which seemed to be well operated so far as sanitary conditions were concerned, but which was in a bad way financially. The authorities had been so absolutely confident of making money out of sewage farming that for years they had carried a deficit in their accounts instead of writing it off to profit and loss, expecting to make it up in time. But within the last year or so Lieutenant-Colonel A. E. Jones, of Finchampstead, Berkshire, who is a strong advocate of sewage farming, and Mr. Avis, manager of a large sewage farm which I visited at Nottingham, and another gentleman who is a farmer, have been appointed as an advisory committee to help the Reading people put the sewage farm on a better financial basis.

The Sandhurst Military Schools have a neat sewage farm of 13 acres. The sewage is received in small detritus tanks with sloping bottoms. The sewage runs into the upper end and flows down over the sloping bottom, and then overflows from the tank. In that way, grit, sand and the like are taken out and the land is relieved to some extent. An old man there was attending to the sewage farm, without any help further than a gypsy boy to scare off blackbirds from newly sown grain. At the time of plowing and cultivating, horses and men are brought over from the Aldershot sewage farm, which is also under the charge of Colonel Jones, to aid in the work.

Aldershot Camp has a large population, both of men and of horses. It is one of the large military camps that one finds everywhere in England. This camp has a varying population of from 20,000 to 30,000 men, and there are many thousand horses there at times. The stables are drained to the sewage farm. The Aldershot Camp farm was in very bad repute for a number of years and there was a strong effort made to secure its abandonment; but Colonel Jones took hold of the matter and by handling the farm in an engineering way he has stopped pondage, and has everything in good shape. Although there is a hospital overlooking the farm there is no complaint. He has no trouble in disposing of the milk from the farm. The cow barns were in very fine sanitary condition. A record of the milk produced by each cow is kept. Colonel Jones makes a monthly report on the operations of the farm. When he balances his books at the close of the year he considers the deficit as the net cost of sewage disposal.

At Aldershot Town there was originally quite an area in land treatment. The sewage is now received in large reservoirs and pumped to contact beds. From the contact beds the sewage goes to still another set of beds which are operated as intermittent filters, and there is land still in use for the reception of the storm-water.

Birmingham and vicinity, including some 800,000 population, has one of the largest and most interesting of the sewage works in Great Britain. A number of municipalities are combined as the Birmingham, Tame and Rea Drainage District. Mr. John D. Watson is engineer of the board. Mr. Watson went to Birmingham about 1900. He found chemical precipitation followed by broad irrigation on an immense sewage farm of some 2800 acres. He made some bold changes: he stopped the use of chemicals, sold off a large number of the cows and struck out on new lines generally. He is now treating the sewage of Birmingham and vicinity by a process or succession of processes that render the works, I think, the most elaborate and costly in the world.* The sewage is received in large tanks which are divided into sections so that the first and smaller section serves as a grit chamber. The deposit of sand is removed from the grit chamber by a dredge. The liquid flows on into another chamber, which is operated more as an ordinary settling tank or reservoir. From this settling chamber the sewage goes to the septic tanks. From the septic tanks the sewage flows some five miles to Dortmund tanks. The Dortmund tanks, as some of you probably know, were named from a place in Germany. They are circular tanks with conical shaped bottoms like those used at the Columbian Exposition, in 1893. The Dortmund tanks take out some of the large amount of suspended matter that comes through the septic tanks. From the Dortmund tanks the sewage goes to two different sets of beds; that is, part of it goes to a group of percolating filters with revolving arms, and part to another group of percolating filters with fixed distributors.

At the time of my visit (March, 1904) portions of the works were in progress of construction, and not all the sewage was treated by the combined processes which I have outlined; but the Dortmund tanks were under construction, and some of each of the two sets of percolating filters were being built. There were three or four different percolating filters making use of different materials and having different distributors.

The percolating filters with revolving sprinklers, at Birmingham, are composed of large pieces, some of coke, some of gravel

* I mean, of course, unit cost and not total cost.

and some of stone. Beginning at the bottom, the pieces of material are perhaps as large as one's head, after which they diminish in size. The filtering material in some of these filters is laid up to form its own enclosing walls, to a height of 7 feet. The filters are circular, and the sewage is admitted through a central pipe to a revolving distributor. Three or four different kinds of revolving distributors were in use at Birmingham, but the most likely ones were apparently those with radial arms, perforated, operating on the reaction principle, something like a revolving lawn sprinkler, and distributing sewage over the beds in small streams or drops.* There is a very elaborate distributor or revolving sprinkler on one of these beds, which might be called a series of revolving weirs; that is, there is a long iron or steel trough divided into sections so the sewage is distributed in thin sheets over weirs placed end to end. To keep the weirs level the inventor provided a big truss, supported on a pivot at the center and running on wheels, and a track at the outer end. A motor mounted on the wheels drives the device. I will not undertake to tell the cost of the distributing apparatus, but it runs up into the hundreds of pounds. Mr. Watson says this is the most perfect distributor yet evolved, but that it is so expensive as to be impracticable.

At the other percolating filters in Birmingham the sewage is distributed by means of fixed pipes, fitted with spray nozzles.

All the percolating filters have open drains at the bottom, so the sewage can pass through continuously and not be held up, as it is in the contact beds. The percolating filters are in some respects like our intermittent filters, except that they are composed of much coarser material and have a very open drainage system.

At Birmingham an expensive system of floors and underdrains is being used for some of the filters. All the filters have heavy concrete floors beneath them, and the underdrainage system of some of the filters is composed of continuous drain tiles (patented), set as close together as they can be placed. I should say, offhand, that the cost of the drain tiles, or certainly the drain tiles combined with the concrete floor on which they are placed, would exceed the cost per acre of our American intermittent filters; but the percolating filters treat the sewage at a vastly higher rate than do intermittent filters.

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* In some places the sprinklers are operated intermittently and in others continuously. Where started and stopped alternately the sprinklers are sometimes called by the awkward name, intermittent continuous filters, but it seemed to me the concensus of practice in England was tending toward using the term percolating filters instead of intermittent continuous or trickling filters.

This elaborate combination at Birmingham is going to involve a large capital outlay, and we shall have to await figures for both construction and operation before knowing whether the saving in operating expense will warrant such high initial cost. Mr. Watson is certainly a very able and courageous man. He has revolutionized the sewage works of Birmingham, and to men accustomed to the uncertain tenure of office in American municipalities it is interesting to hear Mr. Watson talk as if he expected to stay there ten or fifteen years and carry out his plans for this plant, which is being constructed very slowly, indeed.

Mr. T. Howard Barnes.—What rate do they expect to obtain in the percolating filters?

Mr. Baker.—They expect rates running up to 1,200,000 U. S. gallons per acre per day. At other places in Great Britain much higher rates are claimed; as high as and sometimes double or treble the usual rates for slow sand water filtration, where there is no organic matter to deal with. But they are not attempting bacterial filtration; they are attempting to make a non-putrescible effluent.

Mr. Freeman C. Coffin.—Will the final results be that they will gain in this regard at Birmingham, or will there be more expense than by the old way?

Mr. Baker.—When you come to take interest on the plant and sinking fund and the heavy capital charges into account, it seems to me very questionable whether they will show a net saving. They will still have a large part of their 2800 acres of land for the reception of sewage and sludge.

Mr. Coffin.—Do they expect to get better results?

Mr. Baker.—They expect better results, and of course the population of the district is rapidly increasing. It is expected that the new Birmingham water supply which was introduced this summer will raise the water consumption. Besides, at the time I was in Birmingham they were using thousands of pan and pail closets, which will gradually be replaced by water closets, and still further increase the water consumption. In all that section of England, thousands and thousands of pan and pail closets are still in use, and in some places where they do have water closets, they catch the waste water from the sinks and store it up in tip-tanks, to flush out the water closets, or waste-water closets, as they are called.

At Salisbury the sewage works are combined with the refuse destructor. This practice is getting to be quite common in England, and is a very interesting development. The refuse is brought to

these refuse destructors and burned, and the heat generated by the burning of the refuse is used to raise the steam, and the steam is used to pump the sewage, and the clinker from the refuse destructor is used for the so-called bacteria beds.

Salisbury first proposed to depend wholly upon the septic tanks, followed by percolating filters, but it was compelled by the Local Government Board to add secondary filters. At Salisbury, fixed distributors are used for the percolating filters, consisting of corrugated iron sheets specially molded with very sharp angles, with notches cut through the higher angle and lower angle, and with nails inserted in the lower rows of holes. The idea is that the sewage will trickle down and drop off the nails and also drop through the upper notches and thus be evenly distributed. Mr. F. Wallis Stoddard, of Bristol, is very enthusiastic over this method of distribution, which was devised by him. He claims that contact beds are utterly wrong, and that with his system of percolating filters he can get rates as high as 6,000,000 to 8,000,000 U. S. gallons per acre per day.

Mr. Coffin.—Does the septic tank take out enough of the solid matter to prevent clogging of the different sprinkling arrangements?

Mr. Baker.—No, the care-takers have to give the sprinklers attention. The perforations in the tubes, I was told at one of the works, have to be kept open by swabbing them out. Obviously such sprinklers would not work with the thermometer down to 30 or 40° F. below zero.

At Exeter, Yeovil and Barrhead they have septic tanks and contact beds installed by the Septic Tank Syndicate. The small Exeter tank, as is generally known, was the first to be built by Mr. Donald Cameron. The Local Government Board insisted that the large septic tanks and contact beds should be supplemented by land treatment, so an area of land was provided and the sewage is going over this land; but the land treatment seems to be carried on in a perfunctory manner. The authorities were not required to underdrain the land, and the method of distribution which I saw permitted a great deal of the effluent to find its way through the ditches into the river, without much land treatment.

At Yeovil, an insolating pool, also called an aërating pool, was provided. It is a large shallow tank, filled in at the bottom with broken stone. The effluent from the first contact bed comes down into and flows slowly across the pool. The idea was that the sun and air would aid the process very materially. But they still had to provide land for the treatment of the contact bed effluent.

The borough surveyor went with me to the septic tanks at Yeovil and had all the manhole covers taken off. He found the septic tanks nearly filled with sludge. In some places the sludge came nearly up to the surface of the sewage, but when we got down to the outlet end, much less sludge was found. It is only fair to say that the surveyor had been ill, and meanwhile the works had apparently been neglected. The Yeovil sewage is difficult to deal with, as it contains much refuse from leather manufactories, with many pieces of leather in it.

At Manchester, the engineering work is more like American practice than what I saw elsewhere. Dr. Gilbert J. Fowler is both superintendent and chemist of the sewage works,* and the designing engineer associated with him is Mr. J. P. Wilkinson, Assoc. M. Inst. C. E., of Manchester. They are putting in a far less expensive construction than at most of the British works, and are abandoning chemical precipitation, as fast as possible, for septic tanks and single contact beds. They propose, if they are compelled to, to build secondary contact beds, and they also have land in reserve, which can be utilized for broad irrigation. In addition there is a large area of special filter beds for storm-water, and instead of letting those storm-water beds remain idle between storms a certain amount of sewage is applied at frequent intervals to keep the beds in good bacterial condition.

At Salford, I saw chemical precipitation tanks, roughing filters and percolating filters. Here Mr. Joseph Corbett, the borough engineer, has one bed $5\frac{1}{2}$ acres in size, entirely undivided by partitions. He has a system of cast-iron distributing pipes laid at frequent intervals and set with nozzles, so that when he turns on the sewage he gets a multiplicity of nozzle sprays, and sprinkles the sewage over these beds.

At Chadderton, I found in the chemical precipitation tanks an arrangement for removing the sludge without drawing off the sewage, consisting of perforated pipes moved by means of overhead wheels. A rubber squeegee is placed behind and immediately below the pipe so that the perforated pipe is moved along the bottom of the tank and the squeegee pushes the sludge forward. On opening a gate or valve the head of the sewage forces the sludge through the perforated pipe by gravity. The manager said the device worked satisfactorily. A similar device is used elsewhere in circular chemi-

* Dr. Fowler has recently been appointed consulting chemist to the Manchester works in order that he may devote himself chiefly to private practice.

cal precipitation tanks. In such cases the perforated pipe swings radially inside.

Chadderton is an illustration of how numerous sewage works are in Great Britain. I stumbled upon it when I was hunting for another plant. The manager said that so long as I was there I had better see his works, and when I got through looking it over, all I had to do was to jump over the fence and I was on the grounds of the one for which I was searching.

These were the Oldham works, consisting of sedimentation tanks and contact beds. The settled sewage is distributed on the contact beds by wooden troughs. Wooden troughs for distributing sewage are more common in England than I should have expected.

The sludge at Oldham contains a large amount of grease; and Mr. A. H. Valentine, the chemist of the works, who was formerly an assistant of Dr. Fowler, at Manchester, is trying to have the sewage committee put in the necessary plant for recovering the grease. There is one day of the week that it is particularly heavy, and he found, on inquiry, that the reason of that was that everyone ate tripe the day before.

At Accrington and Church, one of the earliest systems of revolving sprinklers was put in use, first known as the Whittaker, and afterward the Whittaker & Bryant, and then the Candy-Whittaker. The London company now promoting this sprinkler has the high-sounding name, The Patent Automatic Sewage Distributors, Limited. At Accrington, as well as at some other places having percolating filters, sedimentation tanks are provided to remove the large amount of matter that goes through percolating filters.

Mr. Barnes.—May I ask Mr. Baker how large the settling tanks are?

Mr. Baker.—Very small, indeed, not enough to serve for more than probably an hour or two hours' flow.

At Burnley, I found one of the best managed plants that I saw. The material from the contact beds (called mill ashes or furnace ashes, really cinders from factory furnaces) was being taken out, washed and replaced. Some new material was also being placed in one of the beds, and I was astonished to find that it was so very soft that I could punch it to pieces with my umbrella. It is surprising that in so many English plants, material should be used that breaks down so easily.

Glasgow was particularly interesting, because notwithstanding all the fervor with which people in Great Britain are adopting the bacterial processes, this city is constructing several new chemical precipitation plants, and this after having made some experiments

on the newer processes. Mr. A. B. MacDonald, the city engineer of Glasgow, is very confident that he can get all the purification that is needed from chemical precipitation, and that it will be very much cheaper, and that the other people in Great Britain will find that they have made a mistake in being in such a hurry to take up with some of the new processes. He is putting in some fine plants. He has built two elevated cast-iron tanks, each of 1500 long tons capacity, for the storage of the sludge. Sludge storage tanks are in use in London also; and in London, as well as in Glasgow, the sludge is loaded on steamers and finally dumped in salt water.

Prof. L. P. Kinnicutt.—Do they dry much of their sludge? They claimed five years ago that they could dry it.

Mr. Baker.—I think they have given that up.*

At York, Mr. Creer, city engineer, has put in what he calls experimental filters, but they are really on a working scale; they are of the percolating sort. He has made some extensive studies and has read some interesting papers before the British societies, giving the results that he has obtained. He has made some modifications, and, if I remember rightly, he has adopted the name "York filter."

At Leeds, chemical precipitation is still employed, but there, as I have stated elsewhere, may be seen a veritable museum of experimental plants. About everything that anyone could conceive of as a possible means of treating sewage has been tried, and new methods are being tested as they come along. Unfortunately for others, at least, the council has stopped publishing the results of its investigations. After making an elaborate report, in 1900, it concluded to utilize some land bought for a sewage farm. The opposition to the farm pointed to the reports on the experiments as proof that the newer processes were very efficacious. The authorities were sorry that they had published the reports, and discontinued them. Since I was at Leeds, engineers have advised the use of three pipes about 47 inches in diameter to convey the sewage to proposed new works, owing largely to the fact that the outfall sewers would pass over some coal land which is pretty badly undermined, making it desirable to keep the weight of the conduits down to the lowest figure possible.

The large sewage farm of 1950 acres, at Nottingham, and its managers are particularly interesting, since Mr. Arthur A. Avis, the present manager, has been some eight years in charge of the

* In revising my remarks I find by reference to my notes that some of the sludge is passed through a Cummer (American) dryer, then screened, ground to powder, and sold under the name of "Globe Fertilizer."

farm, and, before that, was for ten years assistant to his father. Mr. Avis, Sr., laid out the works about 1879, and continued as manager until his death, in 1897. That is an instance of the way municipal works are conducted in Great Britain.

At Salisbury, the city surveyor, who had been in office for some years, told me that he had succeeded his father, and I learned subsequently that his father was city surveyor for fifty years. At several refuse destructors and sewage works I took pains to find out how many years the manager had been in charge, and often it was surprising how long he had been in office. If the works had not been long in use, then the chances were that these men had been previously engaged by the city in some other capacity. Periods of service varying from twenty-five to thirty years are quite common. The hardest thing that I had to try to explain in Great Britain was why we changed our municipal officials so often. They said, "Why, I should not think it would work well; I should not think you would get good results." I said, "We do not." They wanted to know why we continued to change, and I tried to explain why, but I could not make them understand.

At Leicester, which is nearly the last place on my list, sewage is pumped 180 feet and then disposed of on the densest clay soil that can be imagined. The land was underdrained for farming purposes before it was taken over as a sewage farm. The purification effected is so poor that it is necessary to pick up the sewage by a system of intercepting sewers and spread it over the land a second time. There is an arrangement by which it can be applied a third time when necessary. This is another example of what good engineering will do. Mr. E. George Mawbey, M. Inst. C. E., has contended against these great odds, and got along very well, indeed; but he has done it by close attention to details and by turning over the soil repeatedly. Compared with others, he does not go much into dairying and raising crops. Some experiments have been made at Leicester, and it is proposed to enlarge the small settling tanks put in single contact beds, and continue to apply the sewage to land.

The last plant I visited was at Hampton, and there I found a so-called hydrolytic tank in process of construction. It was one of the most interesting things I saw. The original works were built in accordance with the ideas of Mr. Dibdin, in the early days of contact beds. He put in triple contact beds, but they were found insufficient as the sewage and population increased. Recently Mr. Shone and his partner, Mr. Ault, as engineers, have been advising and co-operating with Dr. W. Owen Travis, of Hampton, in the

perfection of the so-called hydrolytic tank, which is the idea of the latter. To state briefly the character of that tank: The sewage enters two side compartments and a central compartment of the tank. The side compartments have sloping false bottoms perforated with slots at the acute angle at the bottom, so that the sludge will pass down through the slots into the central compartment; 90 per cent. of sewage goes into the side compartments and 10 per cent. goes into the central compartment. The theory is that it is not necessary for sewage to remain a long time in a septic tank; that if the sludge can only be retained the larger volume of sewage may be allowed to pass out. I was particularly interested in this, because in the early days of the septic tank I made known some of my ideas on that subject and stated that it seemed to me unnecessary to retain the sewage more than a few hours. In Great Britain it is retained say twenty-four hours.

As has been stated, the only basis of classification of the processes in use at the various works visited has seemed to be the final treatment employed. Even this has to be modified for a few works, such as Exeter and Yeovil, where, to satisfy rulings of the Local Government Board in the earlier days of septic tanks and contact beds, supplementary land was provided. Of the twenty-four works visited, five employ sewage farming, three chemical precipitation, eleven contact beds and five percolating filters for final treatment. The five sewage farms and the three chemical precipitation plants are the sole as well as the final methods of treatment, except for grit chambers at two of the farms and small settling reservoirs, really grit chambers, at another farm. Leicester proposes preliminary treatment by settling tanks and single contact beds at its sewage farm. London contemplates abandoning chemical precipitation for septic tanks, aëration and single contact beds. Leeds has been experimenting for years with the idea of substituting some of the newer processes for chemical precipitation. The eleven works with contact beds and the five with percolating filters are not, in every case, treating all their sewage by those methods. In some instances, the works are gradually being converted to one or the other method, and in some the two methods are being used side by side.

The preliminary treatment at the majority of the sixteen combined works is affected by septic tanks, nearly all of which are open. In a number of cases, however, either sedimentation or chemical precipitation is in use, and while this is only temporary, in some instances, in others it is proposed to continue one of those processes.

The foregoing summary of the methods in use at the works

visited appears to remove much of the previously mentioned confusion as to British practice. It will be observed, however, that it does so by eliminating details. Going a step further in the latter direction, and leaving specific works out of consideration, the general status of sewage treatment in Great Britain may be summarized as follows:

Of the older processes of sewage treatment, chemical precipitation and broad irrigation are still widely practiced, with a strong but by no means universal tendency to abandon the former, and also with a notable clinging to broad irrigation where suitable land for the purpose is available. Plain sedimentation is in use in more places than one might suppose, and it would not be surprising to see it grow in favor, particularly as a sequence to percolating filters. Intermittent filtration does not have the meaning abroad that it does in America. It is chiefly an adjunct of sewage farms, for use when either the growing crops or cold weather does not permit broad irrigation alone, and it is used here and there alongside of contact beds or quite independently of other final processes. For the most part, however, intermittent filtration in Great Britain is merely intensified land treatment for a year or so on particularly favorable sandy or gravelly areas.

Dr. Barwise, in the new edition of his "Purification of Sewage" (London and New York, 1904), states that the intermittent filtration area should be used for a year and then turned back into the sewage farm, and that it should then have seven years rest, so that the intermittent filtration area would be used only once in seven years. That shows how different it is from our understanding of intermittent filtration areas.

Of the newer processes of treatment, notwithstanding a multiplicity of names and of details of construction and operation, it may be said that they fall under three heads: (1) Septic tanks, (2) contact beds, (3) percolating filters. My impressions are that by far the larger number of the septic tanks are open, that no questions of patent rights have yet been brought into court where open tanks have been built, and that the closed septic tank is generally regarded as a patent monopoly.

There are many more contact beds than percolating filters, but that is at least partly accounted for by the fact that the contact bed is the older of the two. The percolating filters seem to be rapidly gaining in favor.

I have not touched upon questions of cost of construction and operation, amount of sludge produced or reduced by septic tanks and rates of treatment by means of contact beds and percolating

filters. This omission is largely due to a lack of suitable comparative data, and also largely to the fact that local conditions affect all these questions so materially as to make any statements likely to be misleading, unless accompanied by more qualifying data than can well be given here.

Before concluding, I wish to speak briefly of the contact and filtering materials used abroad, and of the relation of the Local Government Board to sewage works. Almost every imaginable contact and filtering material available has been tried either experimentally or in practice: coke, coal, cinders or clinkers, burned clay, broken pottery and brick, broken stone and gravel. Probably the material most commonly used is clinker, preferably that from refuse destructors. Gravel and broken stone have been seldom used on a working scale, largely because they are so expensive in most parts of Great Britain, but partly, it appears, because it is thought that there is more virtue in the other materials. Sand is too fine for either contact beds or percolating filters, and in most localities is not to be had at a low price. It seems probable that as the years go by the value of more permanent materials than either ordinary clinkers or coke will be realized, and that where well vitrified refuse destructor clinker cannot be obtained, gravel or broken stone will come into more general use.

Mr. Dibdin is now pushing slate as a material for contact beds; he has taken out patents on what he calls "Multiple Contact Beds," and he is using waste slate from quarries, laid flatwise, with slats to separate the pieces, and in that way getting a very large open space. He is claiming good results.

Of the Local Government Board I will only say that as a rule permanent loans for sewage works in England must be approved by it before the works can be built, or else the loans must be sanctioned by Parliament. The latter appears to be too expensive for any but the larger municipalities, and does not seem to be often employed by them. This power of the Local Government Board gives it virtual control over sewage treatment in Great Britain, down to small details, if it chooses. Much dissatisfaction over the conservatism of the board was felt when the septic tank and the contact bed first came to the front, and no little grumbling is still heard in some quarters. The board, however, is less strict than formerly about the provision of land for the treatment of sewage from the so-called bacterial processes, but it has not yet come to what is generally considered a rational view as to the treatment of storm-water. Its old rule was to require works of sufficient capacity for the full treatment of storm-water up to three times the dry weather

flow, and special works for treating the excess up to a total of six times that quantity. In other words, where the dry weather flow is 1,000,000 gallons a day, septic tanks and contact beds, for instance, must be able to deal with 3,000,000 gallons a day and storm-water beds with 3,000,000 additional. Most sewerage systems in England, it may be added, are on the combined plan.

The Local Government Board conducts no experimental work, but has a staff of so-called engineering and medical inspectors, members of which are detailed to hold hearings on applications for loans. The tendency of the board, as might be expected, is wholly conservative. The need of a central general investigation of methods of sewage treatment was felt some years ago, and, as a result, a new Royal Commission on Sewage Disposal was appointed. The commission has been making some extended studies of various methods of treatment, largely of works in operation, and has issued several preliminary reports. All eyes are turned to the final report of the commission, which is expected soon. It is hoped that this report will do much toward making less onerous and more rational the requirements of the Local Government Board, and that it will materially aid in lessening the confusion now caused by the many rival methods, or, more properly, modifications of methods, of sewage treatment in Great Britain.

DISCUSSION.

The Chairman.—The Massachusetts State Board of Health, as we all know, has done valuable work in experimenting on sewage disposal. Mr. H. W. Clark, the chemist of the Board, has had charge of the work and perhaps he would discuss the matter. We should be glad to hear from him.

Mr. H. W. Clark.—Mr. President, I do not wish to discuss here the English filters for sewage disposal, because I know nothing about them, except what I have read. I thought, however, it would be of interest to bring down here to-night some samples of effluent from filters of a somewhat similar kind which we have in operation at Lawrence.

I have here four effluents; one from an intermittent sand filter, two from trickling, or percolating filters, or, to use the usual title that I have given them, "intermittent continuous filters," and one from a contact filter.

In the first place, I have an effluent from an intermittent sand filter put in operation fourteen years ago, and which is constructed of five feet in depth of sand. This effluent was collected about two

weeks ago. This filter and its results have been written about so fully in the reports that there is little to be said about it here. However, I wished to show a sample of the effluent that you might see its fine appearance.

I have here, also, the effluents of two intermittent continuous filters, one operating at Lawrence and one at Andover. The Lawrence filter is constructed of cinders, and the Andover filter of broken stone. The sample from the filter at Andover is contained in bottle No. 222. This filter is constructed of about 76 inches in depth of broken stone, the stone varying in size from stone 8 or 10 inches in diameter at the bottom of the filter to stone 1 or $1\frac{1}{4}$ inches in diameter at the top. The filter is 17 feet 4 inches in diameter, and sewage is distributed over it by means of an automatic V-shaped tipping basin into which the sewage flows. This filter operates at the rate of 1,500,000 gallons per acre daily. It was put into operation more than a year ago, and through last winter the sewage was applied below the surface of the filter by means of small galvanized iron channels over the edge of which the sewage flowed; that is, during the winter we did away with the tipping basin. As you know, last winter was a very cold one, and these channels were only a slight distance below the surface, yet this filter worked beautifully throughout the entire winter. The temperature of the sewage as it passed to the filter was about 50° F., although it comes through about two miles of pipe from the village of Andover. The sewage lost only two or three degrees of heat in passing through the filter.

The effluent at the present time, as shown in this bottle, contains a great deal of suspended matter, but this suspended matter settles out very readily. The nitrates in this sample were 2.77 parts per 100,000, and it is non-putrescible. I am perfectly willing to have the paper cap taken off, in order that you may see how little odor the sample has.

I have also here the effluent of another intermittent continuous filter, which is less than six feet deep and constructed of cinders. It operates at the rate of 1,000,000 gallons per acre daily. This effluent contains more sediment than the other, but this sediment also settles out in a very short time. This sample is also non-putrescible.

In a third bottle I have an effluent of a coke contact filter, about five feet in depth, and operated at the rate of 550,000 gallons per acre daily. The nitrates are practically absent from this sample, yet nitrates have been formed while sewage was passing through the

filter, but afterward reduced, the oxygen of the nitrates being used to further oxidize organic matter.

In regard to matter in suspension in this effluent; you know if sewage has 30 or 40 parts per 100,000 of matter in suspension, it means that the sewage contains about 1 pound of dry matter in every 350 gallons of sewage. The matter in suspension in the effluents that I have here is very much less in amount and its nature is quite different from that of the sewage matter. If you take the sediment from Lawrence sewage and dry it, this sediment will lose perhaps 60 per cent. on ignition, while the sediment from these filters will lose about 30 per cent. The sewage sediment will contain about $2\frac{1}{2}$ per cent. of nitrogen by weight, while the sediment in the effluent will contain about one-half that amount. It has seemed in studying these effluents that some method of determining approximately and quickly the amount of matter in suspension would be of considerable value, and I have lately established at Lawrence a standard for reading the turbidity and sediment of the effluents of sewage filters, based upon the actual amount of matter of this nature in suspension in these effluents. In this standard, 0.01 of a gram of matter in suspension in a liter of water gives a reading of one part of turbidity, and by this standard the amount of matter actually in suspension in the effluent of various kinds of sewage filters can be determined much more accurately than by any other turbidity standard that can be used in laboratory work in the examination of such waters. Since the first of June of the present year, this standard has been used at Lawrence, and in the report of the experiment station for 1904, the turbidity and sediment of the effluents examined there will be given in the terms of this standard.

Mr. Barnes.—Are there any nitrates in the effluent from the six-foot filter?

Mr. Clark.—Yes, it is marked on the bottle, 1.33 parts.

Mr. Fuller.—I understand you distributed the sewage below the surface in one instance?

Mr. Clark.—During last winter we did.

Mr. Fuller.—How far below?

Mr. Clark.—I think it was six inches below; I am not quite positive, however, in regard to this. I think that in spite of low temperature we could have kept it nearer the surface, because we had such a coating of snow over the filter.

Mr. Fuller.—Do you know whether it filled the entire superficial area?

Mr. Clark.—Of course we don't know that, but we know it filled a good portion, or we should not have obtained the results we did.

Mr. Fuller.—Could you continue to distribute it that way without having difficulty with the iron pipes?

Mr. Clark.—I could not answer that. I think in the course of time we should have to attend to them. I would say, however, that we have deeper percolating than I have mentioned. We have filters ten feet in depth operating at the rate of 2,000,000 gallons per acre daily, and the filters have been operating four or five years and are still open, showing no more clogging than they did soon after beginning operation.

Prof. Leonard P. Kinnicutt.—It is now two years since I last had the pleasure of studying the various English plants for the disposal of sewage, but I feel, after listening to Mr. Baker, that the next best thing to seeing for myself the work that has been done since that time is to see it through Mr. Baker's eyes.

The clear and interesting account that he has given us of his visit to England shows, I think, first of all, the conscientious work that is being done in trying to solve the question of sewage disposal, and I believe, also, it is not an indication of failure or lack of progress that we see in England so many different experiments and methods being tried, but only a sign that we are rapidly learning that different methods are required to meet different local conditions. The serious problem at the present time is not whether sewage can be satisfactorily treated, but what method of treatment is best adapted to meet all the requirements of a particular locality, including the character of the sewage.

The London sewage plant is most impressive, if for no other reason than from the volume of sewage that comes to the plant each day, and it is a plant where not only very much can be learned regarding the treatment of sewage with chemicals, but also as to the seriousness of the problem of treating 200,000,000 gallons per day by bacterial methods. The careful experiments of Professor Frank Clowes, given to us in his reports on the "Bacterial Treatment of London Crude Sewage," show the possibility of treating London sewage otherwise than by chemicals, yet the undertaking is one not to be entered upon lightly, and as Mr. Baker has said, it will probably be many years before bacterial treatment will be substituted for the present method.

Sewage farming finds its strongest advocate in Colonel Jones, and I believe there are certain conditions, unfortunately occurring only too seldom, when this method can be successfully applied. We have, however, traveled far since the day when this method was thought to be a panacea for all our troubles, but that day is vividly recalled to mind when one sees at Barking the beginning of a

tunnel which was to carry the sewage of London far away into the country to be sold, I know not at what price per thousand gallons, to fertilize the soil.

Birmingham, Mr. Baker tells us, is at the present time one of the most interesting of all English cities for those who wish to study the modern bacterial methods of sewage treatment, and in this I most thoroughly agree, for at Saltley, a few miles from Birmingham, are the disposal works of the Birmingham, Tame and Rea District, under the direct charge of Mr. John Duncan Watson, one of the most thoughtful and capable of England's sanitary engineers, who has, during the past four years, not only radically changed the method of treatment of the sewage of this district, the mean dry weather flow averaging 22,000,000 gallons per day, but has also been making experiments on the bacterial treatment of sewage, on a scale which makes much of the experimental work done elsewhere seem Lilliputian in comparison.

From 1872 to February, 1901, the method of sewage treatment at Saltley consisted of chemical precipitation followed by broad irrigation. The chemical treatment consisted of adding milk of lime, 12 grains of lime to the imperial gallon, and passing the sewage through sedimentation tanks. The amount of sewage thus treated between 1890 and 1900 averaged about 20,000,000 gallons per day, and the volume of liquid sludge, containing 90 per cent. of water, equalling about 260,000 cubic yards, was disposed of by trenching it into the soil. The amount of land owned by the Drainage Board up to 1882 was only 272 acres; this amount has been gradually increased till the area at the present time amounts to 2830 acres, of which 1780 acres are used for broad irrigation, the number of persons served per acre being 451.

In 1901, under the advice of Mr. Watson, the above system was radically changed, the addition of lime to the sewage was suspended, and the deposition tanks began to be used for septic action. As a result there was a saving of $15,000 to $20,000 a year for lime, and a reduction of 25 per cent. in the amount of sludge formed and not a deterioration, as some had feared, of the effluent from the subsequent land treatment, broad irrigation, but a gradual improvement. Not content with the advance thus made, Mr. Watson began experiments on bacterial treatment, using $\frac{1}{4}$-acre areas, and planned a very large addition to the plant, which is now approaching completion. This addition is situated in the district of the borough of Sutton-Coldfield, about five miles from the outfall sewer at Saltley, and the effluent from the septic tanks at that place is brought in a conduit of some six million imperial gallons

capacity, allowing of some considerable saving of septic tank capacity at Saltley. The sewage from the conduit enters an intake chamber, in which there is an apparatus regulating automatically the flow of the sewage into Dortmund tanks. These are five in number, and serve to remove the suspended matter in the effluent from the septic tanks. These tanks, according to a private communication received this week, "Arrest more than 70 per cent. of the matter in suspension in the septic sewage, so that the septic effluent that is run upon the primary percolating beds is as free from suspended matter as there is any practical need for." There are five of these primary percolating experimental beds, four of which are circular, each having an area of one-fourth acre, and one is rectangular, of one-half acre area, and different methods of spraying the sewage are used on the different beds. From these percolating beds the effluent runs to a sedimentation basin, to arrest the humus which is always found in effluents from percolating filters. An installation of four secondary experimental percolating beds, each an acre in area, is now being constructed, so that if desired the effluent from the sedimentation tank can be run upon these beds instead of upon the land.

Percolating filters, as we all know, are the most modern of the various bacterial methods, and were first tried, if I am not mistaken, at Accrington, under the direction of Colonel Whitaker, and the percolating filter has often been called the Whitaker filter, and there seems to be no question that in this way a greater amount of sewage can be treated per acre than by any other method. The construction of these filters is not necessarily very costly, nor their maintenance, when taken into consideration with the amount of sewage treated, though they require rather constant attention and supervision. I think Mr. Baker will agree with me when I say that this method should receive careful consideration from American engineers.

Possibly I cannot better close these few remarks than by calling to your attention the two following tables which are given in Mr. Watson's most excellent lecture on "The Purification of Sewage," delivered at the University of Birmingham, in February, 1903, which, as far as I know, cannot be obtained in this country in printed form.

Table Showing Quantity of Sewage Purified by Means of Contact Beds in 24 Hours per Acre of Bed, with Average Percentage of Purification on Crude Sewage.

Name of Town or District.	Time During Which the Beds Were at Work.	Depth of Bed.	Quantity of Sewage Treated in 24 Hours per Acre of Bed.	Average Percentage of Purification.	
				Oxygen Absorbed.	Albuminoid Ammonia.
	Years.	Feet.	Imp. Galls.	Per cent.	Per cent.
Single Contact:					
Croydon	2	3.75	635,625	63.8	60.7
Manchester . . .	4.5	3.33	459,000	75	70
*Birmingham . . .	1	4.5	500,000	80	79
Double Contact:					
Blackburn	2	5.5	600,000	75 to 80	97.1
Burnley	5	3	193,000	87.0	84.8
Carlisle	2	4	905,700	71.0	61.0
Leeds	2	5 and 6	500,000	95	90
Sheffield	3	5	1,000,000	87 to 90	92
"	3	3.33	650,000		
* Note.—This result is obtained from averaging three different single contact beds, as follows:					
Coal				94.6	85
Clinker				75.5	82
Slag				70	70

Table Showing Quantity of Sewage Purified by Means of Percolation Bacteria Beds at Various Places in 24 Hours per Acre of Bed, with Average Percentage of Purification on Crude Sewage.

Name of Town or District.	Time During Which the Beds Were at Work.	Depth of Bed.	Quantity of Sewage Treated in 24 Hours per Acre of Bed.	Average Percentage of Purification.	
				Oxygen Absorbed.	Albuminoid Ammonia.
	Years.	Feet.	Imp. Galls.	Per cent.	Per cent.
Leeds.	3½	9	1,000,000	95.0	90.0
Accrington	3	8 to 9	1,936,000	90.0	91.3
Birmingham	½	5	1,000,000	86.3	88.4
Hyde.	3	9	2,178,000	85.7	90.0
York.	1	6.5	2,129,600	84.5	90.0
Rochdale	2½	9	1,936,000	84.0	84.2

THE CHAIRMAN.—We have with us a member of the Connecticut State Board of Health, Mr. T. H. McKenzie, and we should be very glad to hear from him, if he has a word to say.

MR. T. H. MCKENZIE.—Mr. Chairman and gentlemen: I had no thought of being heard, but I would like to ask Mr. Baker, with reference to the septic tanks he found in use in England, as to whether there were objectionable odors from those tanks, or odors which were noticeable at any distance, and whether or not the effluent of those tanks was turned into the stream without any subsequent treatment.

MR. BAKER.—In no case that I saw was the effluent turned into a stream without further treatment, and I did not notice bad odors from septic tanks or from any sewage works of any kind that I visited.

MR. MCKENZIE.—I mean the uncovered tanks.

MR. BAKER.—Yes. I began my visits in March, and most of them were made in March and April, before the weather had become warm. In warmer weather it might have been otherwise.

MR. MCKENZIE.—I suppose the sewage freezes in the tanks in winter.

MR. BAKER.—Freezing does not seem to be considered. I was told in London that the ground was not frozen once all last winter. Farther north perhaps it would freeze.

MR. MCKENZIE.—And you found the general practice there was that the sewage remained in the tanks twenty-four hours under septic treatment?

MR. BAKER.—I should say the general practice was to allow it to remain from twenty to twenty-four hours, but as I stated in the paper, one should be very cautious in making statements relating to sewage works practice, because with everything in such a transitory stage it is hardly fair to go into much detail.

MR. MCKENZIE.—I think you said you found that the Local Government Board approved of septic tanks?

MR. BAKER.—The matter is almost wholly under the control of the Local Government Board, and it is approving septic tanks, provided they are followed by other processes—final processes of treatment. Inland, I do not suppose the Local Government Board would approve the septic tank as the sole means of treatment. In a seaside town it might. There are comparatively few seaside towns treating the sewage, except by screens, or some such rough and ready means.

MR. MCKENZIE.—I understand you did not find that intermittent filtration was much in use either through natural soil or through artificially constructed beds.

Mr. Baker.—The intermittent filters there are mostly selected areas of sewage farms, chosen because they happen to contain a little sand, or a little better sand, or a little gravel, and such areas are used to ease up on the farms.

Mr. McKenzie.—I am not prepared to discuss the subject to-night, as I did not know that I was to be called upon.

The Chairman.—We are very glad to hear from you. Are there any other questions to be asked?

Prof. Kinnicutt. Did you see any plowing of coal into the soil for intermittent filters?

Mr. Baker.—I did not see anything like that, but I saw sludge being trenched in at Birmingham.

ISTHMUS CANAL: SEA LEVEL VERSUS LOCKS.

By William W. Redfield, Member of the Engineers' Club of Minneapolis.

[Read before the Club, April 20, 1903.*]

To make this paper as brief as possible, I will refer to a previous paper of mine, upon the same subject as this paper is to treat of; said paper appeared in the Journal of the Association of Engineering Societies of May, 1900, Vol. 24, No. 5 and page 207. In that article there was a thorough ventilation of the arguments, *pro* and *con,* in reference to the three routes of Nicaragua, Panama and San Blas.

The author is still, as he was then, totally in favor of the San Blas route, and for full, detailed information in regard thereto he respectfully refers all inquirers to the aforesaid article.

The question then naturally arises: Why was the San Blas route not chosen? and why was the Panama route selected and negotiations therefor initiated? Was it because the Panama route was found, on inspection, to be a more feasible route, from an engineering point of view, than the other two? Not at all. Reasons of state, etc., rendered it apparently necessary to select the Panama route, in order to secure a right for *any* canal whatever across Colombia.

If the original plan for a sea-level canal at Panama had been adhered to, the difficulties hereinafter mentioned would undoubtedly have forced a change of route to that of San Blas. But the lock system was subsequently adopted by the French Company and considerable work was performed upon the canal. The Panama Railroad was adjacent to the canal route. The concessions granted by the Colombian Government to the French Company had to be transferred to the United States and sufficient treaty rights acquired by our Government from Colombia. This, in a measure, committed the Government to the Panama route and at least seemed to require an initiative upon that basis.

But it does not necessarily follow, that cool, sober second thought should not ultimately prevail; nor does it act against the idea of securing a strip of territory across Colombia, in width 50 to 60 miles, extending west of the Panama route and east of the San Blas route, on which to locate suitably the right canal. Then would naturally follow an exhaustive topographical survey of said entire area, thereby ensuring, beyond doubt, the best route in every respect,

* Manuscript received December 15, 1904.—Secretary, Ass'n of Eng. Socs.

and work could be commenced on the canal with confidence that no mistake was being made.

Now, if the present arrangements are carried out, what follows? A canal, if no serious drawbacks occur, would be built on the lock system, having a summit level of 125 feet above mean sea level, and with a summit reach of about 21 miles in length. The *Review of Reviews* for January, 1902, says: "The Commission estimates that the work done on the Isthmus by the late French Company and the plant of the Panama Railroad itself would be worth about $34,000,000 to the United States, if our country were to acquire control of that route and execute the work according to the project approved of by the Commission."

That means that the United States would save an expense of $34,000,000 in completing the canal, which certainly is an advantage for the Panama route. That, however, as I will show, is *all*.

A dam to restrain and regulate the flow of the Chagres River will be necessary. This would cost many millions, and is absolutely essential in order to maintain the summit level constantly at the elevation of 125 feet above mean sea level. To all this must be added the cost of completing the unfinished portions of the canal itself and all the miscellaneous expenses, and the total cost will be enormous.

After the cost of construction comes the expense of maintenance and operation.

Being a canal with locks, such maintenance must be incessant and especially at the Chagres River dam. The latter would be an uncertain quantity and would be a constant menace, no matter how carefully constructed.

Now a few points may properly be brought forward in reference to the San Blas route. This route is located about 30 to 50 miles east of the Panama route; is 29 $\frac{17}{100}$ miles long; has a summit ridge of 1142 feet above mean sea level. But only for seven miles is the surface of the ground above 300 feet; for about five miles it is between 300 feet and 80 feet above mean sea level, and the balance of the length is less; ten miles is of exceedingly light construction. Or, instead of canal proper, a tidewater stream could be improved and utilized for canal purposes.

The entire line is straight from end to end; is a sea-level route, requiring only a tidal lock at each end; has no expensive dam or locks to constantly protect, maintain and operate.

The high ridge of 1142 feet elevation may stagger many, and the question may well be asked: Why was the Panama route originally on a sea-level basis, and having a summit ridge of only

some 400 feet in elevation, afterward changed to a lock system canal? Was it because by deducting 125 feet from 400 feet made it less difficult to pass the summit ridge? No. If the 400 feet of ridge had been *all* that stood in the way, the French Company would have had a sea-level canal completed and in successful service to-day.

The reason consists not in the *height alone* of the ridge. If that had been all, a few hundred, or even thousand, feet more in height would have delayed the completion a few months longer. The essential difficulty is due to the disastrous floods of the Chagres River and, in a lesser degree, to those of the Rio Grande River, along whose valleys the routes of both Panama Railroad and canal had been located.

Right here, attention is called to a scientific distinction that should be borne in mind between locating a railroad route or a canal route. A railroad is located essentially on the *surface* of the ground and may, in some cases, be exactly on the surface, or on an embankment entirely; but a canal is always in excavation (excepting aqueducts for crossing of streams.) A railroad has ascending or descending grades on inclined planes; is practically located on the surface; is placed in the lowest pass over or through a ridge or divide, more for economizing simultaneously the cost of construction and of maintenance and operation when completed. If a railroad is built on a straight line and on a level grade, it will cost much to construct and to maintain, and little to operate. If the grades are made as heavy as the limit allowed, and the curvature be as sharp as the allowed limit, and the lowest pass be made use of, the first cost would be reduced; the cost of maintenance might possibly be also reduced, but the cost of operation would be materially increased.

First cost is a quantity used only once; maintenance and operation are quantities that are repeated as long as the road exists. Therefore it is necessary in locating a railroad to average judiciously the following conditions: Shortest route; the lightest curves; easy grades; minimum quantity of material removed; and, as a rule, it is necessary to utilize the lowest passes for overcoming summits.

On a canal route, however, the conditions and requirements are wholly different; and *that* is the "rock upon which many have split."

An ideal canal route (irrespective of size of canal) requires an equalized combination of all or *most* of the following conditions: The shortest and straightest route; as few locks as possible (none

at all, if possible); good harbors at each end; economy of construction, considering duly the nature of soil, streams to be encountered, dams to be built, ease of handling and removing of material.

Now, with this as a general statement, to be specific—

The San Blas route has a great advantage, in spite of that 1142 feet in height, and seven miles of either tunnel or deep excavation. It is an anticlinal route; the Panama route is a synclinal route. The Panama route is synclinal because the waters flow toward the canal route and have to be taken care of.

The San Blas route is anticlinal, because the waters (and fortunately in a less volume) flow *away* from the canal route in *both* directions. What does this mean? It means less difficulty in excavating to sea level; it means a strong chance of drier material to be handled and removed. As to the choice of tunnel or open cut at the summit ridge, it must be admitted that in either case the quantity in cubic yards would be vastly greater than at Panama; but being in all probability drier than that at Panama, where even with the summit level at 125 feet above sea level a large portion of the excavation must be below the bed of the Chagres River, it will be seen to be many times cheaper to remove.

If open cut should be chosen instead of tunnel, the increased number of cubic yards would take but little more time to remove; for a portable railway system with cars and tracks galore would suffice for quick removal of material.

In regard to the comparative cost of maintenance and operation of the two routes it is axiomatically in favor of the San Blas route.

Now, in order to cite some authorities, let us take a brief extract from an appendix to a speech made in the United States Senate by Senator N. B. Scott, of West Virginia, on February 6, 1902:

Note 7.

Charles Prelini, in his "Practical Treatise on Tunneling," published 1901, gives the following table of cost of excavation in different kinds of soils, based on his examination of the actual cost of constructing many different tunnels through formations of like character, the number of which is given:

Nature of Soil.	No. of Tunnels.	Cost per Cubic Yard
Granite gneiss	56	$3.07 to $3.85
Schist	39	1.38 to 1.53
Triassic	3	—— ——
Jurassic	69	1.23 to 1.38
Cretaceous	34	.61 to .77
Tertiary and Modern	39	.33 to .61

Note 8.

An examination of the cost of the four great tunnels of the world—Hoosac, Mount Cenis, St. Gotthard and Arlberg—discloses the fact that the Arlberg, while one-third larger than the Hoosac cost $2,700,000 less, and was built in one quarter of the time. The Hoosac to-day could probably be built for one-half of the cost of its construction. Their relative cost per foot was:

Hoosac	$379
Mt. Cenis	356
St. Gotthard	229
Arlberg	154

In conclusion it may be said that many great men are advocating the San Blas route, and several of them firmly believe that *there* will eventually be constructed a great sea-level ship canal which will be on soil American, protected and controlled by the United States —a guaranteed world's highway for all time.

OBITUARY.

Kilburn Smith Sweet.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

KILBURN SMITH SWEET died July 15, 1904, after a brief illness, at his summer home at Quincy, Mass. He was born in Ramsey, Minn., February 25, 1872, the youngest of four sons of Capt. Thomas M. Sweet, who had served through the Civil War in the 24th Regiment, Massachusetts Volunteers. The father's health had been ruined by the exposures of army life, and in the year following the birth of this son he died. Two years later the mother also passed away. Deprived of his parents, the boy was dependent for a home upon other near relatives, with whom he lived most of the time until the age of seventeen. He then entered the Massachusetts Institute of Technology, and in 1893 was graduated from the course in civil engineering.

In the ensuing fall he returned to the Institute as assistant in civil engineering, later becoming instructor and remaining in that position until the time of his death. His time was divided between instruction in hydraulics, surveying and stereotomy. He was modest and unassuming in his ways, clear and direct in his thinking, and one who quickly won the interest and confidence of his students.

From the time of his graduation from the Institute his summer vacations were, with few exceptions, devoted to practical engineering work. He was thus employed on surveys, investigations or construction for the city of Newton, the towns of Winchester and Hopedale, the Associated Factory Mutual Insurance Companies, the Metropolitan Water and Sewerage Board, the Committee on Additional Water Supply for the City of New York, and the United States Geological Survey. Just previous to his death he had begun a summer engagement with Mr. Leonard Metcalf, member of this Society.

He joined the Boston Society of Civil Engineers in April, 1897, and at the time of his death was a member of the Committee on the Library, to the work of which he had for more than a year given much time. He was also a member of the New England Water Works Association.

In September, 1900, Mr. Sweet married Miss Jessie Louise Johnson, who survives him. He was a man of strongly religious character, which was quietly but consistently displayed in his conscientious performance of duty, in his readiness for every reasonable service, however humble, in his appreciation of the success of others, and in his patience and helpful sympathy toward his students.

DWIGHT PORTER,
CHARLES M. SPOFFORD,
Committee.

Association of Engineering Societies.

Vol. XXXIII. SEPTEMBER, 1904. No. 3.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Directors' Meeting, San Francisco, Cal., May 13, 1904.—Held at the residence of Mr. Adolf Lietz, at San Rafael, which was preceded by a dinner, to which Mr. Lietz had invited the Directors for the purpose of getting them together and discussing informally the final arrangements for the spring meeting.

Present: Directors Dickie, Riffle, Schild, Wing, Uhlig, Lietz and von Geldern.

After the dinner the business before the Board was brought up by the Secretary and disposed of, after which the meeting adjourned, the guests returning to San Francisco.

Otto von Geldern, *Secretary.*

Spring Meeting, San Francisco, Cal., May 26, 27 and 28, 1904.—Officers—President, George W. Dickie; Vice-President, Franklin Riffle; Secretary, Otto von Geldern; Treasurer, E. T. Schild.

Directors—C. E. Grunsky, Adolf Lietz, Carl Uhlig, H. D. Connick and L. J. LeConte.

Committee—Past President E. J. Molera; Prof. C. B. Wing.

First evening (May 26th)—Reception to members and friends held in the hall of the Academy of Sciences.

The meeting was called to order by President George W. Dickie, who announced formally the opening of the first meeting and gave the general information for the itinerary of the next day.

The address of welcome was then delivered by the President, who referred to the past work of the Society and of its great future possibilities in influencing many lines of commercial development on the Pacific Coast. This interesting address will be published in full as a part of the Transactions of the Society.

The following telegram was received from Panama Canal Commissioner C. E. Grunsky, and was read by the President:

"Washington, May 26, 1904.

"Greeting to members and assembled guests. I wish all full measure of profit and enjoyment and success to first spring meeting.

"C. E. Grunsky."

Mr. F. P. Medina read a paper on the subject of the "Construction, Laying and Testing of the Commercial Pacific Cable," which was illustrated by various samples of cables for shore end, intermediate and deep-sea purposes.

Meeting adjourned until 2 P.M., May 27, 1904.

Second day (May 27th)—An excursion was arranged by Mr. Carl Uhlig to visit the Union Iron Works. A steam tug left the water front at 9.30 o'clock for the Potrero, where the attending members and their guests were entertained by Mr. Dickie and the officers of the establishment. The visitors were shown all the interesting objects, being taken from one to another of the shops by guides, who had previously grouped them, so as to explain and point out intelligently the great mechanical features to be seen here.

After the visit the party returned to the steamer, where the Committee on Entertainment, consisting of Mrs. Schild and Mr. Uhlig, had prepared a luncheon, enjoyed by all, after which the visitors returned to the city.

Second day (afternoon session)—Meeting was called to order at 2 P.M., by President Dickie.

The minutes of the evening session of May 26th were read and approved.

Mr. John Richards read an exhaustive paper on the subject of "Steam Turbine Motors," which, for lack of time, was not discussed, but upon suggestion by Professor Marx was confined to written communications to be sent to the Secretary.

Prof. F. G. Hesse read a paper entitled "Jet Pumps," in which a theoretical treatment of the efficiency of this kind of pump was made the main subject of discussion.

Mr. Marsden Manson presented an interesting paper entitled "The Reclamation of a Mountain Swamp," which was discussed by E. J. Molera.

Meeting adjourned until 8 o'clock P.M.

Second day (evening session)—The meeting was called to order at 8 o'clock P.M., by President Dickie, who announced the itinerary for the next day.

The minutes of the previous meetings and sessions were read and approved.

The following applications for membership were made and referred to the Board of Directors for ballot:

For members:

1. Robert Schorr, mechanical engineer, San Francisco. Proposed by A. E. Chodzko, Adolf Lietz and C. E. Grunsky.

2. Charles H. Parcell, civil engineer, city engineer of Sausalito. Refers to C. E. Grunsky, John Richards and George H. Wallis.

3. O. Holmer Phelps, heating and ventilating expert. Refers to Hermann Kower, F. G. Hesse and E. T. Schild.

4. Ralph E. Parker, civil engineer, Narrows, Oregon. Proposed by Marsden Manson, E. F. Haas and H. D. Connick.

The following papers were then read and opened for discussion:

1. "Pipes and Joints for High Pressure," Franklin Riffle.

2. "Vertical Railway Curves," H. I. Randall.

3. "Armored Concrete Construction," M. C. Couchot.

4. "Experiments in Driving Piles for a Foundation with a Steam Hammer," J. J. Welsh.

5. By title: "Skeleton Steel and Hollow Concrete Block Construction," S. Giletti.

Meeting adjourned.

Third day (May 28th)—A special car left Market and Fifth Streets at 10 A.M., in charge of Mr. H. D. Connick.

The party visited the power house at Eleventh and Bryant Streets, and also the so-called "Big Cut" of the Sante Fe Railway at Eighteenth and Iowa Streets.

The excursionists returned to the city by noon.

Third day (May 28th, afternoon session)—Called to order at 2 o'clock P.M., by Past President Molera.

The following papers were read and opened for discussion:

1. "Consideration of Uplift as Affecting the Design of Masonry Dams," Chas. D. Marx.

2. "Portland Cement Manufacture," C. J. Wheeler.

3. "Collection and Discussion of Material in County Highway Bridges," C. B. Wing.

The meeting thereupon adjourned, and the spring meeting ended with a banquet, held at the Palace Hotel, in the evening.

OTTO VON GELDERN, *Secretary.*

At the Banquet, held May 28, 1904 (Spring Meeting of the Technical Society), at the Palace Hotel, the following toasts were drunk and replies made, some of which are hereto annexed in full.

President George W. Dickie presided as toast-master, and called upon the speakers to respond.

1. The Technical Society of the Pacific Coast, Past President E. J. Molera.
2. The American Society of Civil Engineers, Mr. A. L. Adams.
3. The Electrical Engineering Fraternity, Mr. F. P. Medina.
4. The Mechanical Engineers of the Country, Past President John Richards.
5. The Architects, Our Co-workers, Mr. Henry A. Schulze.
6. The Relation of the Engineer to the Merchant, Mr. Charles Bundschu.
7. The Wives of the Engineers, Mrs. C. E. Grunsky.
8. The Improvements of OUR Rivers, Past President Marsden Manson.
9. The Removal of Telegraph Hill, Mrs. Chas. Bundschu.
10. The Engineer and the Astronomer, Professor A. O. Leuschner.
11. Our Glorious State—California, Mr. A. T. Herrmann.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS, MR. ARTHUR L. ADAMS.

Mr. President, friends and wives of the members, and the members themselves, of the Technical Society of the Pacific Coast: You have placed the members of the American Society of Civil Engineers, residing in and about San Francisco, under lasting obligation to you, by extending to them, as you have, a very courteous and cordial invitation, regardless of their membership in this society, to attend your meetings, and particularly to attend at this banquet. On behalf of these members I wish to express to you my most hearty appreciation of your kindness and of the great

benefit which I have derived by listening to the very able papers which have been presented at this Spring meeting. They certainly would be a credit to any organization anywhere.

It is always easier to listen than to speak, even though it be not more pleasant sometimes. By your kindness you have a right to ask that I say something. I really know of no valid reason why I should not. It is not given to us all to speak words of wit and humor, which are always so welcome on an occasion of this kind, but it is at least given to each one of us, by expressing his views, to incite thoughts in the minds of others which may be of much greater value than those which he himself expresses.

It has been very kindly expressed to me that there is no restriction placed upon my selection of the subject upon which I should attempt to speak. I have noticed in the invitation which you have extended that the purpose of this meeting and of this banquet was to excite professional and social interests. The subject is broad. It has occurred to me that I might say a few words, which under these circumstances are certain to be of interest, not only to the members themselves, but to their wives (because I know wives are always interested in that which interests their husbands), upon what the California engineers have done for the engineering profession. In the early time, as the result of God's handiwork, this great state was spread out,—a state, I am sure, which, the longer we dwell in it, the more fully and forcibly are we impressed with its greatness, and with the wonders of its natural resources. He spread out upon the East the great mountains, upon which He lets fall, winter after winter, rain and their covering of snow. At their feet He spread out the great valleys, almost without rain, yet in every other respect of wonderful fertility. He spread out these great forests. He filled these mountains and these valleys with gold. And to this great opportunity He invited the people of the East,—indeed, the people of the world,—saying: Enter in, and take possession. It has been said that the Almighty gives no finished work to the hands of man. While that is true, He does give the engineer, in order that his work may be made finished. To the engineer He said: Enter in to this golden state, and prepare it for mankind. Make plain the way. Make possible the opportunities for the development of a great people. It is interesting for us to note in what way, and to what extent, response has been made to this call,—a call, certainly, no less divine, because it was extended to men of practical affairs, than is the call divine to that profession which preaches His Word. As the result of the work of comparatively few men, which accomplishment some now living may look back upon from its beginning, the bridle trail has been replaced by the railroad. The work has been done thoroughly, so far as external appearances go; and so far as those nicer problems relating to the adjustment of grades and construction cost to volume of traffic, that results may be given in haul at the least cost per ton mile, we have no reason to think that these problems have not been as carefully studied, as fully solved, in the case of California roads, as on any roads in the world.

The mining engineer has entered in, and from these rocks and these valleys he has taken gold to the hundreds of millions of dollars' worth; and he is to-day taking it from these mountains and these valleys in quantities second to only one other in the Union of States.

The irrigation engineer has entered in upon these valleys, almost barren of rain. Upon them he has brought the life-giving water, as a result of

which the coyote and the cactus have given place to the olive and the orange, and, may I add, too, these beautiful flowers which you see spread out upon this table before us in such profusion.

In place of the Indian canoe, which at one time navigated our waters, we have now sent forth from this city the very pinnacle of the engineer's accomplishments—these mighty battleships;—ships created—need I hesitate to say it—under the genius of your President, of such merit that it is recognized that none of greater efficiency are manufactured anywhere.

Our mountain streams are being transformed into electric currents for transmission over the longest lines in the world in commercial use. They have been brought to the centers of population, and are there bringing light into the dark places. We have before us this evening, as we sit around these tables, these beautiful lights, which in all probability are produced by energy emanating from these sources; and if not produced from these sources, are produced by a genius no less wonderful, no less meritorious, exercised upon our local generating stations.

To attempt to review all that the California engineers have done for the engineering profession in this state, would be to recite the history of California, with reference to its horticulture, its agriculture, its commerce,—yes, and even its social life. In the few minutes available I can do no more than thus briefly recite what has been accomplished. It is of exceeding interest, however, to trace, even in a few sentences, the process of evolution by which the engineer has wrought out this present condition. The original incentive to the coming to this state of its people was the promise of gold. The immediate problem which confronted the engineer was the extracting of that gold, and as a result of his study there were produced several epoch-making devices. For the using of the water of the streams, upon which he seized at once as a source of power for the solution of his problem, it was necessary to conduct it along precipitous mountain sides, and in many places across deep canyons. His genius rose to the occasion, and he was equal to the conditions confronting him,—conditions of scarcity of money and absence of means of transportation other than the backs of man and beast. He produced the steel-riveted pipe. He used it in the lightest gauges under pressures which were phenomenal, and which would have been appalling to the hydraulicians of other countries. He evolved a type of pipe which has become standard in engineering, and which is now in use practically everywhere.

In studying this problem he also produced another invention, only less important than that mentioned, the hydraulic giant, by which the water, brought from these distant sources under great pressure, was made to tear the earth asunder, and to separate, by means of other devices, the gold from the gravel. How nicely has the mechanical engineer stepped in and supplemented this whole invention. He saw the necessity for cheap power. He saw this tremendous energy issuing in the jet of the hydraulic giant. He applied the impulse wheel, and we have produced another epoch-making invention originated in California. We have the impulse water wheel, a type distinct in itself, a type of great value, a type which the world has come to recognize as of especial value in a field for which nothing else exists, a type of wheel which is now in use in every country of the globe.

In the irrigation of the plains it became at once apparent to the irrigation engineer that water must be stored in these mountain valleys at such

elevations that it could be brought readily to the plains to be watered. Again he was confronted by adverse conditions, difficulties in transportation, the scarcity of money, where great results must be achieved with limited means, and he evolved many striking types of construction; some of them of great value, some of them of great interest as experiments whose real value is as yet not determined. We have originated the rock-fill dam. We have originated the dam of curved plan, depending entirely upon its arched action for its resistance to the water pressure. We have originated the steel-core dam, while here dams of cribwork and dams of earth have been carried to heights still unsurpassed elsewhere.

If I were to take time, and if I had greater familiarity with all the various lines of engineering, I might enumerate many other striking inventions which have been brought to a high degree of perfection on this coast by the engineering profession, and which reflect great honor upon the engineers of this state. The question naturally arises now, as to whether or not there have been rewards for these great achievements. The very fact that these achievements have been adopted elsewhere, that their merits have come to be recognized by the profession at large, is itself the greatest reward. And yet reward has not been lacking in a financial way. It should be a matter of pride to the members of the profession at this day that to California has come the president of the greatest aggregation of railroad capital that has ever existed, to find the brains for the management of that great property, and he has come to the engineering profession to find those brains. It should be a matter of pride with us that the greatest salaries that have ever been paid to engineering specialists have been paid by London capitalists to men trained in the mines of California. It should be a matter of the greatest pride to us that there sit around this board men whom it is unnecessary to enumerate, whose reputation is world-wide.

If what I have said seems to be in the nature of felicitation, it is not because I wish so to be understood. I recognize its dangers. It leads to egotism, which leads to bigotry, and these are ever a drag upon rather than an incentive to progress. I speak thus, however, that we may, as engineers, more fully appreciate the value of our heritage,—the value of that which has been done by the men who have preceded us here in this state; that we may be inspired to greater activity; that we may realize that the acceptance of this heritage imposes a corresponding responsibility, which we must meet if we are to prove ourselves deserving. I speak also in this vein because I am exceedingly jealous of the reputation of the engineering profession in California, and am anxious that it may receive the recognition to which its works entitle it. To this end, it is necessary that we should have a just appreciation of that which the profession here has contributed to the sum of engineering knowledge. And having such appreciation, it is necessary that we maintain at all times that degree of organization, the necessity for which I was so glad to hear your president dwell upon in his address the other evening, which is so essential in order to get before our profession at large a knowledge of the work which is accomplished here.

To this end no influence has contributed so much as "The Technical Society of the Pacific Coast." I am glad that you are already planning the further expansion of that influence; and you may be always assured of the hearty sympathy of the members of the American Society of Civil Engineers, the names of many being on your membership rolls.

The Electrical Engineering Fraternity, by Mr. F. P. Medina.

Mr. Chairman, Members of the Technical Society, ladies and gentlemen: In responding to the toast proposed, I have first to call attention to the social process that has created the engineer; how, in the beginning, when Science and Utility were wedded, the engineer was the offspring of their union. And it would make very interesting matter to trace the history of the engineering professions from ancient times, when, the concept of his possible functions being exceedingly limited, the same individual was at once civil and mechanical engineer and architect, to the present, when function has become so heterogeneous. The Electrical Engineer is the product of this differentiation of functions, which has been going on through the ages, and is the youngest member of the family. So it is no wonder that we look to the future for his greatest achievements, without disparaging his work in the past. Notwithstanding the problems of long distance transmission that have already been solved, it is not too much to expect that the future will see problems of even greater magnitude as well solved; notwithstanding the manifold uses to which electricity has been put in the past—uses, standing to society in a relation analogous to that in which nervous force stands to the individual organism—the future will disclose uses hitherto undreamt of. In the still prevailing controversy over the rightful position of Science in the education of the individual, Science appears to me to be like the little gray-gowned Cinderella, who was destined one day to be transformed into the richly robed princess, and finally to wear the crown and wield the scepter as queen. It is not putting it much too strongly to call Science the mother of civilization, and while, in this practical old world, Utility is honored enough, I say "All hail, to the little gray-gowned Mother of Civilization!"

The Mechanical Engineers of the Country, by Past President John Richards.

Mr. Toast-master, ladies and gentlemen: My friend, Mr. Dickie, is always assigning to me some difficult work. He well knows the vague meaning of Mechanical Engineer. If properly construed, or construed in fact, it covers nearly all constructive work and is chief among the engineering professions. I do not represent the profession to an extent which would justify my selection to speak to this toast. In fact I am a deserter, not so much from choice as from necessity. The art has run away from me and has left me high and stranded after an honest struggle of twenty-nine years in the works.

Somewhere else the result would have been different, but on this coast the mechanical engineer is confronted with a chaos of problems that defy classification. Steam machinery, in its multifarious forms—marine propulsion—mining machinery—hydraulics—pneumatics and half a hundred more divisions of his art, with all of which he may be brought into contact, make up, as I said, an indefinite calling covered by the term "Mechanical Engineering."

We keep pretty well to the front on this coast, notwithstanding the impediments named. One may go into any of our works out here and order a man-of-war, a wheel barrow, a locomotive or an iron fence, and his order will be entered as a matter of commonplace practice. In the Eastern States they enjoy the advantages of organized production in specialized manu-

factures, and by the economy thus gained they relieve us of the great mass of what may be called engineering manufacture, leaving us the special and difficult part and all the risks. Still we manage to keep along, and sometimes we "carry coals to New Castle." In ships of war, cable railways, hydraulic and mining apparatus of all kinds, plowing and hoisting machinery, we have a foremost place in respect to the world's practice.

Not only in machines, but in men, we are well represented. If the members of this Society were withdrawn from the South African mines, it would cause a great change there. Our work is a little rough sometimes, and has to be, because of its cost to produce. A prominent manager in the east said to me, last year, in respect to a machine he was making, "It costs me more to sell that machine than it does to make it." This was true; the selling expense exceeded the labor account. We are not likely to do any of that kind of selling out here. It is a system of production that is not likely to endure and should not endure.

The Improvement of Our Rivers, Mr. Marsden Manson.

Mr. President, although you have been credited with making a great many mistakes, and with having made them a long time ago, and although you have selected for me a subject that cannot be thought a dry one, I think that you have made a mistake in calling on me to talk. It is a grave mistake to call on a man to make a speech after dinner, unless he is a gifted after-dinner speaker.

Tributary to the Bay of San Francisco we have two rivers, and a number of smaller streams. Some of them are even called sloughs. But one of our important cities—Stockton—has grown so great,—so important, in the commercial development of this state, that it does not like the name "slough," and consequently we have "Stockton Channel." The same way with our neighbor Oakland. I was once taken to task for saying that Oakland had no important water front, and I came very near replying that I did not know that Oakland had any water front at all,—that it was worse off than San Francisco; it sold its water front many years ago for a schoolhouse and a bridge, and now has not even the schoolhouse and the bridge. But our rivers are of much importance, not only in the matter of navigation, but as carriers of flood water. They have to pass volumes of flood water through an enormously rich country. Unless those waters are passed in channels designed and arranged by the technical man to fit the duties which they have to perform, enormous damages are done. To-day, the measure of damage done by floods, on the crops that we should have had this summer and fall, is measured in the enormous sum of five millions. Unfortunately, in dealing with those rivers, we have a number of interests to adjudicate. First, the United States government controls those portions which are navigable. Second, the state steps in, and it unfortunately steps in through a non-technical commissioner of public works.

We have "The Sacramento River," conducted by a very good collection of business men. For a number of years it was edited by a good editor, and now an excellent lawyer is ready to write briefs on the subject. I think it is time for our technical men to step forward and take hold of the subject of river treatment, write about it, think about it, study it up. The technical engineers pay attention to these matters. They have studied the conditions in this state, they have brought with them from other states,

and from other countries, a knowledge of what has been done upon other rivers, they keep in touch with the literature of the subject; and yet, in a recent river convention held in this city, in which the interests and development of those rivers were considered, it was practically declared that the technical engineer was not the right man to deal with these questions; that he must be like the reporter who was told by the managing editor that he would like to have a man approach his subject knowing absolutely nothing about it; as he would then be able to write an unprejudiced article from an unbiased standpoint.

In regard to taking hold of a technical subject, the general idea is that you want a man who *does* know something about his subject,—who knows as nearly all about it as it is possible for the human intellect to know. To find that idea reversed was a little of a surprise to me.

Again, this same authority wanted men who had had experience on Mississippi River work. He forgot that, within our borders, were three members of the Mississippi River Commission, all engineers, all trained in that capacity; and yet the idea was advanced, and I am sorry to say it was well supported in that body, that we should have men who knew nothing about California rivers, but who had had experience elsewhere.

In those rivers we have in the neighborhood of a thousand miles of navigable channel. Those channels are being depleted and injured by wash from the hills and by unavoidable mining débris, and it is the province of the engineer to put these channels, not only in their originally good condition, but in a still better condition. Around this bay there centers something in the neighborhood of twenty thousand square miles of rich, alluvial territory. The greater portion of this area is intersected by this thousand miles of navigable channels. We have no idea of the scope of work necessary to put these lands and channels into shape for the best interests of our people, and there lies before us, in this, one of the great fields of work of our profession.

It is not only the civil engineer who has to deal with these problems. The manufacturing and technical chemist must build the works for developing the cement which will be needed in the construction of immense hydraulic works. The chemist will have the waters and the soils of that same region to deal with. The engineer, who devotes himself to railroad work, must not only build the miles of road that will traverse each side of that section, he must cross-section it, gridiron it, with numberless tracks. So we have before us a field of enormous work and a region of enormous wealth.

The Architects, Our Co-workers, Mr. Henry A. Schulze.

Mr. Toastmaster, Ladies and Gentlemen, when it was announced to me that I would be expected to respond to the toast "The Architects," I could not but feel that we had quite a number of the architectural profession in our membership who could and would voice a response in a far happier vein than myself, far more in touch and tune with the festive and professionally fraternal occasion which we are gathered here this evening to participate in and to enjoy and which so fittingly marks the close of our more than enjoyable and profitable spring meeting, yet withal there was no desire on my part to shirk this obligation in favor of some one else in that it occurred to me that at about the middle of my professional career it was my fortune for quite a span of years to have the engineering side of architecture pre-

dominate to a large degree in the activities of my life. During that time my intercourse was fully as much, if not more, with engineers than with architects which thus perhaps put me in closer sympathetic accord with the aspirations and ambitions of each profession than, sometimes, is manifest in its individuals; it is often asserted by our engineer friends, with considerable show of right for a basis in fact, that the architect, through indifference or the cultivation of a poetic, artistic temperament, somewhat willingly allows the warping and clouding of his judgment against what is precise and mathematically capable of demonstration and looks askance, not to say with disdain, on the efforts of the engineer to intelligently apply the materials of construction at hand with the least waste and the least divergence from directness, that the architect but incidently acknowledges that the law of gravity has some subtle associates which are often ignored by him, to which, in reply, the engineer must complacently listen to the assertion that the engineer knows nothing of the subtleness of a line of beauty or the pleasure aroused by the harmony of proportion, that the trend of his education and nature does not bring him to the analysis of that which is beautiful, nor to the esthetic elements which also underlie all construction problems and only to that which is eminently practical and useful.

Each side has indulged in these reflections with some show of justness, much to the detriment of each other and at the expense of high and satisfactory results, beneficial alike to each other; many modern constructive problems involve the intelligent activities of the two professions to such an extent, they overlap and commingle so closely, that it is difficult to determine just where the responsibilities of the one profession end and where those of the other begin, the trend of modern practice being more and more in that direction, therefore, engineer and architect alike should be governed solely by that breadth, largeness and generosity which are characteristic of each of the two professions classed among the most exacting and important of all professions, developing thus to that lofty and gratifying ideal "fraternity" with all its encouraging rewards.

Directors' Meeting, San Francisco, June 24, 1904.—Held at the office of the Secretary.

The Treasurer presented bills for the excursions and banquet of the spring meeting, which were approved and ordered paid.

The following were elected to membership upon count of ballots:

1. Robert Schorr, mechanical engineer.
2. Chas. H. Parcell, civil engineer.
3. O. Holmer Phelps, heating and ventilating expert.
4. Ralph E. Parker, civil engineer.

The Secretary was instructed to notify the members that there would be no meeting during the month of July.

Adjourned. Otto von Geldern, *Secretary.*

Regular Meeting, San Francisco, Cal., August 5, 1904.—Preceded by a meeting of the Board of Directors, called to order at 7 o'clock p.m., by President Dickie.

The purpose of the meeting was to consider the necessary arrangements for the autumnal meeting of the Society.

It was agreed that the most suitable time would be December 9th and 10th. The Secretary was instructed to circulate a notice requesting members to submit suitable papers to be read on that occasion, and to notify the Secretary in time to have the papers set into an outlined program. The meetings are to be held in the Mechanics Library Building, and will be open to the public.

After discussing the details of the proposed meeting and the available locations for excursions, the regular meeting was called to order by the President.

The minutes of the spring meeting were read and approved.

Mr. Dickie left the meeting, and the Vice-President, Mr. Riffle, took the chair.

Mr. H. L. Demeritt thereupon addressed the members on the most interesting subject of "The Removal of Shag Rocks and Arch Rock in San Francisco Harbor," explaining the methods employed by the contractor in drilling, blasting and dredging the material. He referred to the object lessons taught by contact with this comparatively new and hazardous problem, and related in a highly interesting manner the details and causes of failures and the final satisfactory result of this great work.

The Society expressed its appreciation by a vote of thanks tendered Mr. Demeritt.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Association of Engineering Societies.

Vol. XXXIII. **OCTOBER, 1904.** No. 4.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, September 21, 1904.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M. President Frederick Brooks in the chair. Eighty-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. James F. Monaghan and Charles H. Parker were elected members and Mr. Francis E. Adams an associate of the Society.

Mr. J. R. Worcester read a communication from the commission appointed to revise the building laws of the Commonwealth, inviting the Society and its members to submit in writing any suggestions which they desired to make with reference to amendments. Mr. Worcester stated that the commission had been furnished with a copy of the changes adopted by the Society at its March meeting.

The President announced the death of two members of the Society: Kilburn S. Sweet, who died July 15, 1904, and Reuben Shirreffs, who died August 31, 1904.

By vote of the Society the President was requested to appoint committees to prepare memoirs. The President appointed as a committee to prepare memoir of Mr. Sweet, Messrs. Dwight Porter and C. M. Spofford; and to prepare memoir of Mr. Shirreffs, Messrs. A. D. Flinn and J. C. Chase.

On motion of Mr. Wason the following vote was passed, Voted, That the Board of Government be instructed to consider the advisability of inviting the visitors of the Institution of Civil Engineers to Boston, and that they be given full powers to act as they deem best in this matter.

Mr. Sanford E. Thompson then read the paper of the evening entitled, "The Strength of Concrete." The paper was illustrated by numerous diagrams.

A general discussion followed the reading of the paper in which Messrs. J. R. Worcester, Wm. Parker and C. M. Spofford took part.

Adjourned.

S. E. Tinkham, *Secretary.*

SANITARY SECTION.

BOSTON, MASS., OCTOBER 12, 1904.—The regular meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Copley Square Hotel, October 12, 1904, at 7.15 P.M.

The meeting was preceded by a dinner which was attended by 38 members and guests and the attendance at the meeting was 52.

It was voted that the reading of the records of the last meeting be dispensed with.

The following were elected to membership in the Section: Arthur Morgan, Charles W. Ross, William F. Morse.

The paper of the evening was read by Mr. M. N. Baker, associate editor of the *Engineering News*, the subject being "A Recent Visit to Twenty-four British Sewage Works." The paper was discussed by Professor L. P. Kinnicutt, Mr. H. W. Clark and others.

On motion of Mr. H. P. Eddy, the thanks of the Society were voted to Mr. Baker for his interesting and instructive paper.

Voted to adjourn.

WILLIAM S. JOHNSON, *Clerk.*

BOSTON, OCTOBER 19, 1904.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M.; ninety-four members and visitors present.

The record of the last meeting was read and approved.

The following were elected members of the Society: Messrs. Elliot R. B. Allardice, Walter L. Anthony, George P. Frost, George A. Johnson, Albert E. Kimberly, William N. Patten, Charles H. Pierce and John E. Porter.

The thanks of the Society were voted to Mr. Fred E. Ellis for courtesies extended to members of the Society on the occasion of the excursion to the new highway under construction across the Lynn marshes, on July 20, 1904, and to Mr. George Phillips for courtesies on the occasion of the excursion to Moon Island and the Sewage Pumping Station, on September 29, 1904.

The first paper of the evening was by Mr. Frank W. Hodgdon entitled "Boat Harbors on the South Coast of Massachusetts." The paper was illustrated by plans and lantern slides.

The second paper was by Mr. John E. Cheney on the construction of the Cambridge Bridge. This paper was fully illustrated by lantern slides.

Adjourned.

S. E. TINKHAM, *Secretary.*

Engineers' Club of St. Louis.

ST. LOUIS, MO., THURSDAY, JUNE 9, 1904.—The Engineers' Club of St. Louis entertained the members of the British Institution of Mechanical Engineers and the members of the American Society of Mechanical Engineers upon a boat trip up the Mississippi River.

The opportunity for seeing the river at a time of high water was taken advantage of by some 250 members and guests.

The steamer Cape Girardeau, chartered for the occasion, left the dock at the foot of Locust Street shortly after 1 o'clock, luncheon being served on the boat.

The visitors being anxious to see the junction of the Missouri with the Mississippi, the proposed stop at the Chain of Rocks was abandoned, and the trip continued nearly to Alton.

As many of the guests had dinner engagements, the return was so planned that they might meet these engagements, the landing being made at 5.30.

The day was ideal and the trip was in every way a pronounced success.

R. H. Fernald, *Secretary.*

St. Louis, Mo., Saturday Afternoon, June 25, 1904.—About 50 members of the Engineers' Club of St. Louis, with ladies, responded to the kind invitation of the Honorable Adalbert von Stibral, Commissioner-General of Austria, to a private view of the engineering exhibits in the Austrian Pavilion at the World's Fair Grounds.

The guests were cordially received by the Commissioner, and after an inspection of the pavilion were directed to one of the large porches, where refreshments were served.

R. H. Fernald, *Secretary.*

St. Louis, Mo., August 6, 1904.—An invitation was extended to the members of the Engineers' Club of St. Louis to attend a lecture on "Liquid Air," given under the direction of the Department of Liberal Arts, by Dr. Petavel, of the British Royal Commission, in the Jury Room of the Liberal Arts Building.

Those who attended were highly entertained and greatly interested in the lecture, which was well illustrated and especially adapted for the occasion.

R. H. Fernald, *Secretary.*

St. Louis, Mo., Wednesday, September 14, 1904.—The Engineers' Club of St. Louis entertained the delegates to the International Electrical Congress at an informal luncheon, in the main hall and court of the Electricity Building, World's Fair Grounds.

Although somewhat difficult to estimate the number present, the general opinion was that about seven hundred availed themselves of the Club's invitation, which fortunately was the number provided for by the caterer.

R. H. Fernald, *Secretary.*

584th Meeting, St. Louis, Mo., September 21, 1904.—The 584th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 709 Pine Street, Wednesday evening, September 21, 1904.

In the absence of both President Ockerson and Vice-President Moore, Mr. Edward Flad was appointed to the chair.

There were present 18 members and 2 visitors.

The minutes of the 583d meeting and of the special meetings and gatherings held during the summer were read and approved, and the minutes of the 370th, 371st, 372d and 373d meetings of the Executive Committee were read.

The following names were proposed for membership and referred to the Executive Committee for action: Leonard Alleck Day, Halbert Paul Hill, Carl Edward Julihn, Charles Francis Müller and John Bice Turner.

Upon motion of Mr. Brennecke the following committee was appointed by the Chair to investigate the question of new quarters and to report as soon as possible to the Club—one member of the committee to be a member of the present Governing Board: W. G. Brennecke, H. H. Humphrey, E. E. Wall, W. A. Layman and A. H. Zeller.

The paper of the evening upon "Some Experiences as a Municipal Contractor" was presented by Professor F. S. Spalding, of the University of Missouri, and brought out discussions from Messrs. Childs, Broderick, Flad, Helm, Greensfelder and Spalding.

Adjourned. R. H. Fernald, *Secretary.*

St. Louis, Mo., September 24, 1904.—On the evening of September 24, the Engineers' Club of St. Louis gave a smoker in the Missouri Building, World's Fair Grounds, in honor of the members of the American Institute of Mining Engineers, who were visiting the Exposition. Twenty-nine members of the Club were present and about 100 guests.

After brief but happily chosen introductory remarks, Mr. Ockerson, the President of the Club, introduced Dr. Raymond, the Secretary of the Institute of Mining Engineers, who responded in his usual cordial way.

After announcements by Mr. Wheeler, the local Secretary of the Mining Engineers, relating to the entertainment of the visitors, Mr. Klepetko, consulting engineer for the Amalgamated Copper Co., presented a paper on the "Mineral Resources of the United States."

Following this, Dr. E. W. Parker, of the U. S. Geological Survey, described in detail the U. S. Geological Survey Fuel Testing Plant in operation in the Mining Gulch at the Exposition, and extended a cordial invitation to those interested to visit the plant.

Refreshments suitable for the occasion were served throughout the evening, and the informality of the affair was to a large extent responsible for its success.

R. H. Fernald, *Secretary.*

St. Louis, Mo., Sunday, September 25, 1904.—The Engineers' Club of St. Louis was invited, by the local committee of the American Institute of Mining Engineers, to join the American Institute of Mining Engineers and the Jurors of the Engineering Departments for a private view of the exhibits in the Mines and Metallurgy Building.

About 45 members of the Club took advantage of this exceptional opportunity, passes having been furnished through the kindness of Mr. W. B. Stevens, the Secretary of the Exposition. The total number present was about 200.

During the inspection of the exhibits, President Francis, Director Skiff and Secretary Stevens, of the Exposition Company, and Mayor Wells, of St. Louis, dropped in, and after a few impromptu remarks, the company adjourned to the balcony of the building where luncheon was served.

Following luncheon, the party went through the north end of the gulch, giving especial attention to the "Thermit" demonstration and the Fuel Testing Plant, returning in season to take the automobiles for a trip around the grounds and the city.

R. H. Fernald, *Secretary.*

St. Louis, Mo., Friday Evening, October 7, 1904.—The Engineers' Club of St. Louis entertained the members of the International Engineering Congress at a smoker in the Missouri Building, World's Fair Grounds.

Over 50 members of the Club were present together with about 250 guests.

The company met in the large assembly hall, and was called to order by Mr. Ockerson, President of the Club. Mr. Ockerson's introductory remarks were followed by brief, informal "speeches" by Mr. E. S. Corthell, member of the Am. Soc. C. E., New York City; Sir William White, K.C.B., F.R.S., President, Institute of C. E., England; Robert Moore, Past-President, Am. Soc. C. E., St. Louis, and Professor K. E. Hilgard, member Am. Soc. C. E., Zurich, Switzerland.

After the remarks and cigars had been enjoyed, refreshments were served in the various rooms of the building. Music for the evening was furnished by an orchestra and by a vocal quartet.

R. H. Fernald, *Secretary.*

585th Meeting, St. Louis, Mo., October 19, 1904.—The meeting was held at the Club rooms, 709 Pine Street, Wednesday evening, October 19, 1904.

In the absence of President Ockerson, Vice-President Moore presided. There were present 27 members and 6 visitors.

The minutes of the 584th meeting of the Club and the records of the smoker of September 24th and the visit to the Mines building, Sunday, September 25th, and the smoker of Friday evening, October 7th, were read and approved.

The minutes of the 374th meeting of the Executive Committee were also read.

The following were elected to membership in the Club: Leonard Alleck Day, Halbert Paul Hill, Carl Edward Julihn, Charles Francis Müller, John Bice Turner.

Owing to frequent absence from the city Mr. E. A. Hermann found it necessary to tender his resignation as a member of the Executive Committee. The resignation was accepted, and Mr. A. O. Cunningham and Mr. A. P. Greensfelder were nominated to fill the vacancy. Mr. Greensfelder was elected, receiving 14 of the 26 votes cast.

A very complimentary notice regarding the hospitality of the Engineers' Club of St. Louis during the Exposition period, published in the editorial section of the *Engineering Record* of October 15th, was read by the Secretary.

Upon motion of Mr. H. A. Wheeler, it was decided to dispense with the services of the attendant at the Club Rooms at the end of October.

Mr. W. G. Brennecke, Chairman of the Committee on new quarters, made an informal report of progress. He indicated that the Local Chapter of the American Architectural Institute would hardly care to join the Engineers' Club in the new quarters. The Committee had under consideration the following possible places:

1. The present location, 709 Pine Street.
2. Library, down town; meetings elsewhere.
3. Washington University Club, 29th and Locust Streets.

4. Academy of Science, Olive, near Vandeventer Avenue.
5. Y. M. C. A., Grand and Franklin Avenues.

Mr. C. D. Purdon presented his interesting paper upon "The Classification of Engines for Bridge Loading," which was discussed by Messrs. Fay, Moore, Fernald, Mogensen, Purdon, Turner, and Greensfelder.

Adjourned.

R. H. Fernald, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., Monday, October 10, 1904.—The regular meeting of the Civil Engineers' Society of St. Paul was called to order by President Starkey at 8.15 p.m.

Eight members in attendance.

Minutes of previous meeting read and approved.

The secretary was directed to have one hundred membership cards printed.

Messrs. Munster, Bernier and Forbes were named by the President as a committee on society badge to report at the next meeting.

The following applicants were unanimously elected to membership:

Charles Olney Cook, care N. W. Fuel Co.
J. Henry Fitz, 34 Union Block.
T. Milton Fowble, 34 Union Block.
Russell Saville Fuertado, Somerset P. O., Wisconsin.
Nathaniel Hanson, 675 Edgerton Street.
Kristian W. Tanner, Gilfillan Block.
Alfred H. Wheeler, 816 Globe Building.
W. P. Whitten, Gen. Off. G. N. R'y Co.

C. L. Annan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., September 2, 1904.—Called to order by Vice-President Franklin Riffle.

The minutes of the last regular meeting were read and approved.

The following were elected to membership after a count of the ballots: Chas. E. Moore, civil engineer, Santa Clara, Cal.; James C. Bennett, mechanical engineer, Oakland, Cal.; Eugene T. Thurston, civil engineer, San Francisco, Cal.

Mr. H. A. Diehl discussed "Pumice" as a comparatively new and available building material, having gained the conviction that if some material other than the heavy masonry for adorning tall buildings could be found, of lighter weight, yet sufficiently strong to replace the brick, terra cotta and freestone employed at present, some substance which might at the same time be fire-proof, an important departure from ordinary building methods might become possible. The subject was discussed at length by members. The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., October 7, 1904.—Called to order at 8.30 o'clock, p.m. by President Dickie.

The minutes of the last regular meeting were read and approved.

In the consideration of the fall meeting it was agreed that the dates for the gatherings be December 1st, 2d and 3d; that is, on the first Thursday, Friday and Saturday of the month.

The following program for the meeting was arranged:

Thursday, December 1st.

Evening session, beginning at 8 o'clock p.m.

1. Reception and Address of Welcome, by the President.
2. "Hydro-Electric Power Development and Transmission in California," by Robert McF. Doble.

Friday, December 2d.

Afternoon session, beginning at 2 o'clock p.m.

1. "Water Power and Electricity in California," by George W. Nichols.
2. "Hydro-Electric Power Generation from the Consumer's Standpoint," by James C. Bennett.
3. "Engineering and the Law," by Frank P. Medina.

Evening session, beginning at 8 o'clock p.m.

1. "Trade Schools," by Edward T. Hewitt.
2. "Phenomena of Machine Operation," by John Richards.

Saturday, December 3d.

Afternoon session beginning at 2 o'clock p.m.

1. "Fuel Oils, Their Physical Properties," by Paul W. Prutzman.
2. "Durability of the Materials of Masonry Used in San Francisco," by Marsden Manson.
3. "Reclamation of Tidal Areas," or another subject in lieu of this, by Otto von Geldern.

The meetings to close with a banquet to be held at some suitable place to be chosen.

Committee on banquet: Messrs. Uhlig and Schild.

Committee on holding meetings: Messrs. Connick and von Geldern.

It was also suggested that a communication be sent to the Mechanics Institute to request the Trustees to increase the scope of the Technical Library as much as possible, in order to increase its usefulness to engineers and that the co-operation of a committee from the Technical Society be suggested to them for the purpose of adding suitable literature to this part of the Library.

The Secretary was instructed to write such communication to the Trustees of the Mechanics Institute, offering such co-operation if acceptable to them.

Meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Montana Society of Engineers.

THE regular meeting of the Society for October, 1904, was held in the Society Room, 225 North Main Street, Leyson Block, on Saturday, October 8th, at 8 P.M., with President Moulthrop presiding, and a large number of members in attendance. The minutes of the last meeting were approved. The application of Mr. Wm. T. Jackson for membership in the Society was read, approved and the Secretary was instructed to send out the necessary ballots. Treasurer Barker read some new rules under consideration by the Association of Engineering Societies, and was instructed to vote "no" on the section that proposed a yearly tax on all members, active, honorary and associate. Mr. C. W. Goodale began a discussion of the U. S. Mining Laws, but gave way to Mr. Geo. H. Maxwell, who spoke at length, having for his theme, "Irrigation Projects of the United States." An interesting discussion by several members followed his remarks. The members expressed their appreciation of Mr. Maxwell's address by a vote of thanks. On motion, the discussion of U. S. Mining Laws was deferred until the November meeting.

The Society then adjourned.

CLINTON H. MOORE, *Secretary.*

Association of Engineering Societies.

Vol. XXXIII. **NOVEMBER, 1904.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

586th Meeting, St. Louis, November 2, 1904.—Held at the rooms of the Club. President Ockerson presided. There were present 32 members and 2 guests.

The minutes of the 585th meeting were read and approved, and the minutes of the 375th meeting of the Executive Committee were read.

Mr. W. G. Brenneke, Chairman of the Committee on New Quarters, reported that the proposition for having the library down town and meeting room elsewhere was too expensive. There are no possibilities of getting quarters either at the Washington University Club or the Y. M. C. A. The plan seemed to narrow down to the Historical Society or the Academy of Science, probably the latter. The committee hoped to report definitely at the next meeting.

Mr. S. B. Russell, Chairman of the World's Fair Committee, gave an outline of the plans for the reception to the Iron and Steel Institute, Friday evening, November 4th, at the Kentucky Building, World's Fair Grounds. The Secretary added a few details, and explained the proposed visit of the Club to the Mines and Metallurgy Building, World's Fair Grounds, Sunday, November 6th, through the kindness of the Reception Committee of the Iron and Steel Institute.

According to the by-laws of the Club, the following were nominated to serve on the committee to nominate officers for the next year: W. G. Brenneke, S. B. Russell, R. S. Colnon, H. J. Pfeifer, J. L. Van Ornum, E. R. Fish, E. E. Wall and R. L. Murphy.

Of this number the following were elected: W. G. Brenneke, R. S. Colnon, E. R. Fish, R. L. Murphy and S. B. Russell.

Mr. S. B. Russell proposed an amendment to the Constitution, Article III, Section 1, so that it shall read: "The officers of the Club shall be a President, First Vice-President, Second Vice-President," etc.—*i. e.,* providing for two Vice-Presidents instead of one.

Mr. W. G. Brenneke suggested the addition of another Director, so that the Executive Committee should consist of seven members, namely: President, two Vice-Presidents, Secretary and three Directors.

Upon motion of Mr. Flad, seconded by Mr. Russell, the President appointed a committee, consisting of Edward Flad, S. B. Russell and R. H. Phillips, to draw up the necessary amendments to conform to the above

suggestion. The committee was instructed to report at the next meeting of the Club.

The paper of the evening, by Prof. A. P. Winston, of Washington University, upon "The Incorporation of Trade Unions," was listened to with unusual interest, and provoked discussion from Messrs. McCulloch, Borden, Childs, Bryan, Chaphe, Van Ornum, Flad, Turner, Phillips and Professor Winston.

Upon motion of Mr. Zeller, a vote of thanks was extended Professor Winston for his paper.

Adjourned. R. H. FERNALD, *Secretary.*

ON Friday evening, November 4th, the Engineers' Club of St. Louis tendered an informal reception to the members of the Iron and Steel Institute, with their ladies, at the Kentucky Building, World's Fair Grounds. About 70 members of the Institute and ladies were present, and about the same number of members of the Club and other invited guests.

Through the kindness of Mr. Hughes, Secretary of the Kentucky Commission, the Kentucky Building, which is admirably adapted for an occasion of this kind, was reserved for the exclusive use of the Engineers' Club and its guests.

R. H. FERNALD, *Secretary.*

ON November 6th, at 10 A.M., the Engineers' Club of St. Louis was entertained by the Reception Committee of the Iron and Steel Institute at a private view of the Mines and Metallurgy Building, World's Fair Grounds. The total attendance, including the members of the Iron and Steel Institute, the Engineers' Club and invited guests, among whom were many ladies, was over two hundred.

Luncheon was served in the building about 1 o'clock. After a visit to two or three outside exhibits, automobiles were taken through the city to the foot of Walnut Street, where Colonel Thompson entertained the party upon his house boat, which had just arrived from New York.

R. H. FERNALD, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, NOVEMBER 16, 1904.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock. President Frederick Brooks in the chair. About 200 members and visitors present, including ladies.

In the absence of the Secretary, Mr. Richard A. Hale was elected secretary *pro tem.*

The record of the last meeting was read and approved.

Messrs. Joseph P. Palmer and James M. Siner were elected members of the Society.

A memoir of Charles W. Folsom, prepared by a committee of the Society, was read by the Secretary in the absence of any member of the committee.

The President announced the death of James T. Boyd, a member of the Society, which occurred on November 3, 1904. By vote of the Society, the

President was requested to appoint a committee to prepare a memoir. The President has appointed as that committee Messrs. Ira N. Hollis and Frank B. Dowst.

The literary exercises were by Mr. Desmond FitzGerald, who gave a talk on his work in the Philippines and described interesting street scenes in Manila. The talk was illustrated by a large number of beautiful lantern slides.

Adjourned. R. A. Hale, *Secretary pro tem.*

Montana Society of Engineers.

The regular meeting of the Society was held in the Society room, No. 225 North Main Street, September 10th, at the usual hour, with President Moulthrop in the chair.

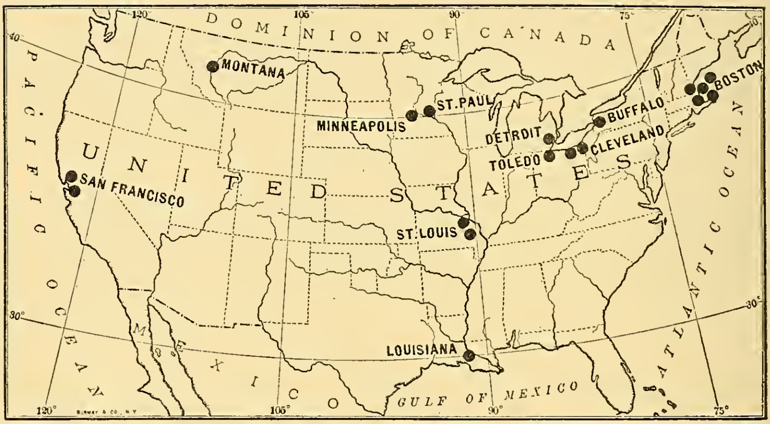
The minutes of the last meeting were read and approved.

The Secretary stated the desire of a member of the Society that the Mining Laws of the United States be made the subject for consideration at an early date, and it was voted to consider the same at the October meeting and that C. W. Goodale be requested to lead in the discussion.

The Chair appointed as a Committee to nominate officers for the coming year, Messrs. Goodale, A. N. Winchell and Word.

Messrs. A. N. Winchell and C. H. Bowman gave interesting talks on World's Fair topics and the industrial training department of Cornell University, after which the Society adjourned.

Clinton H. Moore, *Secretary.*



MAP

Showing the locations of the Societies forming
THE ASSOCIATION OF ENGINEERING SOCIETIES.
(Each dot represents a membership of one hundred, or fraction thereof over fifty.)

Association of Engineering Societies.

Vol. XXXIII. DECEMBER, 1904. No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

587th Meeting, St. Louis, Mo., November 16, 1904.—The meeting was held at the Club rooms, 709 Pine Street, Wednesday evening, November 16th. In the absence of President Ockerson, Vice-President Moore presided.

There were present 45 members and 11 visitors.

The minutes of the 586th meeting were read and approved, and the minutes of the 376th meeting of the Executive Committee were read, as were also records of the reception to the members of the Iron and Steel Institute, held on November 4th, and the visit to the Mines Building with the members of the Iron and Steel Institute on November 6th.

A letter of thanks for the reception tendered the Iron and Steel Institute was received from Mr. H. A. Wheeler, Local Secretary of the American Institute of Mining Engineers, and read before the Club.

The application of Mr. Seth D. Merton for membership in the Club was presented, and referred to the Executive Committee for approval.

Mr. W. G. Brenneke, Chairman of the Committee on New Quarters, presented a final report of the Committee embodying the following statements:

"The Academy of Science proposes to lease to our Club for a period of five years two rooms on the second floor of their building (18 x 25 feet each) for the exclusive use of the Club, and in addition the use of the general assembly room on the first, second, third and fourth Wednesdays of each month; to furnish heat, light and janitor service and keep the quarters open to members at all times. Further, their Assistant Librarian will be in charge of the building during the day. The consideration to be five hundred ($500) dollars per annum.

"In the opinion of your committee, the last-named quarters are by far the most desirable of those examined, and they therefore recommend that the Engineers' Club close a lease with the Academy of Science for the quarters mentioned for the time and consideration stated."

Upon motion of Mr. R. S. Colnon, seconded by Mr. W. H. Bryan, the report of the Committee was accepted, and the proper officers instructed to draw up the proper lease with the Academy of Science for the quarters indicated.

Mr. Edward Flad, Chairman of the Committee on Amendments, presented a report of the Committee embodying certain amendments in the

Constitution and By-Laws, as indicated at the last meeting of the Club. After presenting the report Mr. Flad moved that the Constitution be amended as requested by the Committee, and that the amendments to the By-Laws be taken up in due form. After receiving a second, the proposed amendments were discussed at some length, and upon motion of Mr. H. H. Humphrey the matter was tabled, the vote standing 22 in favor, 19 against.

Mr. S. Bent Russell, Chairman of the World's Fair Committee, reported the proposed entertainment to the Western Society of Engineers of Chicago. The plan outlined by the Committee was to give a dinner to the members of the Western Society and ladies at the Tyrolean Alps, Friday evening, November 18th. Mr. W. G. Brenneke outlined a proposed trip of the Western Society to Thebes to inspect the new bridge over the Mississippi, and stated the arrangements that had been made through the courtesy of the Western Society to have the members of the St. Louis Engineers' Club, with ladies, participate in the trip.

The Secretary read the notice of the proposed dinner for the Western Society, which was to be mailed to members of the Club, and also read the following telegram, which was to be sent to Mr. Ralph Modjeski, of Chicago:

"Kindly extend cordial invitation of Engineers' Club of St. Louis to Western Society of Engineers and ladies to dinner at Tyrolean Alps, Friday evening."

The Secretary also stated that the plan for entertaining the Western Society, proposed by the World's Fair Committee, had been approved by the Executive Committee.

After a few preliminary remarks upon the work now being carried on at the U. S. Geological Survey Fuel Testing Plant, World's Fair Grounds, Mr. W. H. Bryan presented the following resolution:

"Resolved, That the Engineers' Club of St. Louis appreciates the work now under way at the Government Fuel Testing Plant at the Louisiana Purchase Exposition, and regrets the possibility that the unavoidably late start, the early closing of the Exposition, and the exhaustion of available funds, may bring the work to a close before the full measure of its usefulness has been realized.

"The Club heartily endorses the movement to continue the work after the close of the Exposition, and authorized the Executive Committee to present the matter in such manner as may seem appropriate to the owners of the apparatus, the Exposition authorities, our city officials, and the Congress of the United States, with a view of retaining the use of the plant, and site, and of securing funds to continue the work."

The above resolution was approved by the Club.

The Nominating Committee, appointed at the last meeting, presented the following report:

"Your Committee for nomination of candidates for officers of the Club for the ensuing year submits the following names:

For President—Mr. Robert Moore.

For Vice-President—Mr. W. A. Layman.

For Secretary—Mr. R. H. Fernald.

For Treasurer—Mr. E. E. Wall.

For Librarian—Mr. E. B. Fay.

For Directors—Mr. A. P. Greensfelder and Mr. H. H. Humphrey.

For Members of the Board of Managers of the Association of Engineering Societies—Mr. Hans C. Toensfeldt and Mr. C. A. Moreno."

Mr. E. B. Fay, after presenting the many difficulties encountered in moving to new quarters, moved that the Committee on New Quarters be continued and be instructed to look after the moving of the Club to its new quarters. Motion was carried.

Upon motion of Mr. Edward Flad the Chair was authorized to appoint a committee to make the necessary arrangements for the annual dinner of the Club. The Chair appointed the present World's Fair Committee to look after this matter.

The paper of the evening, by Capt. C. H. Smith of the Westinghouse Company, upon the Westinghouse-Parsons' Steam Turbine, was received with marked attention and was discussed by Messrs. Bryan, Langsdorf, Fish, Humphrey, Laird, Russell, Moore, McCulloch, Capt. Smith, and others.

Upon motion of Professor Langsdorf a vote of thanks was tendered Capt. Smith for his paper of the evening.

Adjourned. R. H. FERNALD, *Secretary.*

ST. LOUIS, MO., NOVEMBER 18, 1904.—On the evening of November 18th the Engineers' Club of St. Louis entertained the Western Society of Engineers of Chicago, and their ladies, at dinner at the Tyrolean Alps, World's Fair Grounds. There were 106 members of the Western Society, including the ladies, and between 30 and 40 members of the Engineers' Club, and ladies, present.

Immediately after the dinner mentioned above the company adjourned to the Union Station, where the train was taken for Thebes, Ill., to inspect the bridge across the Mississippi at that point. About 100 members of the Western Society of Engineers, and ladies, together with 32 members of the Engineers' Club and 26 guests, made the trip. The party arrived at Thebes during the night. After breakfast at the Construction Plant the party visited and inspected the east end of the bridge. The river was then crossed for an inspection of the concrete arches and west approach to the bridge, after which a trip was made to the railroad yards. After luncheon, at 12.30, the party returned to St. Louis, leaving Thebes about 1.30 o'clock.

R. H. FERNALD, *Secretary.*

The Civil Engineers' Club of Cleveland.

CLEVELAND, DECEMBER 13, 1904.—The regular December meeting of the Club was held in the Electricity Building of the Case School of Applied Science, and was called to order by Dr. D. C. Miller, Vice-President, at 8.30 P.M. Present, forty-one members and visitors.

The tellers, Messrs. C. O. Palmer and W. C. Clark, reported the election to active membership of the following: W. Orien Brosius, John P. Dowd, C. E., Andrew B. Lea and S. G. Werner.

The following applications for active membership, approved by the Executive Board, were read: H. S. Johannsen, J. R. Poe, B.S., and Arthur E. Spooner, C. E.

The Secretary read a communication from the Secretary of the American

Society of Civil Engineers, announcing the decision of the Society to hold its next annual convention in Cleveland during the last week in June, 1905.

The paper of the evening, "The Use of the Engineering Laboratory in Education," was read by Professor Benjamin, who afterward illustrated his subject by showing to the Club the new power laboratory of the school with its various machinery and apparatus in operation.

Lunch was served in the laboratory.

JOE C. BEARDSLEY, *Secretary.*